This issue:

A Progress Report of the Cedar Creek Natural History Area
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CALL FOR PAPERS

The Fifty-second Annual Meeting of the Minnesota Academy of Science will be held at the College of St. Thomas in St. Paul on April 27 and 28, 1984. Any member wishing to present a research report at the Annual Meeting is asked to provide the following information to the chairperson of the appropriate section by February 6, 1984. A form for reporting the information is available from the section chairperson.

- Exact title of paper
- Name of author (including title)
- Institution of author
- Time required
- Audiovisual requirements
- Other special requirements

Again this year every person presenting a paper will be required to submit an abstract. Abstracts will be published in the *Journal of the Minnesota Academy of Science* and will be available before and at the meeting. Instructions for the preparation of the abstract and the reproduction form are available from section chairpersons or the Academy office.

Members wishing to have their reports considered for publication in the MAS Journal must deposit the manuscript with the section chairperson at the time of presentation. Members not making oral reports must deposit manuscripts with the section chairperson before April 28, 1984. Academy membership is not a prerequisite for publication, but in the event that space limitations require that a selection be made among equally qualified papers, those submitted by members will be given priority. The editor reserves the right to reject or to defer publication of any manuscript received later than the above dates or that does not meet the stated requirements for publication.

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Fish Culture in Minnesota Farm Ponds

MEREDITH O. MURYANK AND DENNIS F. MURYANK *

ABSTRACT — This paper presents the results of a three year research and extension project in fish farming in central Minnesota. Fifty-seven farm ponds were stocked with one or more of the following species: channel catfish, largemouth bass, rainbow trout, yellow bullheads, bluegill sunfish, and black crappie. Several stocking densities with and without supplemental feeding were tested. The results indicate that when intensively managed, ponds over 0.05 hectare in size and 1 meter in depth are suitable for the production of food fish. Production of harvestable-size fish is possible during a single season when large fingerlings are stocked in early spring. Trout and catfish demonstrated the highest growth rates. Average yields for different production methods ranged from 18 to 356 kg/ha in warm-water ponds and 114 to 880 kg/ha in cold-water ponds. Fish yields were higher in ponds with supplemental feeding than without feeding. Several harvesting methods were tested and analyzed for efficiency. The findings indicate the importance of proper site selection and pond design for the success of an aquaculture operation. Economic analysis revealed the profitability of trout culture, and relatively high production costs for warm water species. Ways to reduce these costs are suggested.

INTRODUCTION

Aquaculture, the cultivation of aquatic plants and animals under controlled conditions, is becoming increasingly important as a method of food production in the United States today. Farmers are attracted to fish culture because of the high yields possible and the chance to utilize areas unsuitable for traditional crops. Rapid growth in the U.S. catfish and trout farming industries has occurred during the last 20 years, particularly in the Southeast and Pacific Northwest. A recent study in Mississippi indicated that catfish provided the highest financial return per hectare of any agricultural crop in the state (1). Ongoing research and extension programs in this area have contributed substantially to this development.

In the Midwest, the concept of raising fish for food is relatively new (2). Natural lakes in Minnesota have traditionally provided excellent sport fishing opportunities; consequently, the culture of fish in private ponds has received little attention. Climatic conditions such as short growing season, cool water temperatures and severe winters have also deterred aquacultural development in the state (3).

Yet a great need exists to increase the production of food fish for both home and commercial use. According to Minnesota Department of Natural Resources (DNR) statistics, most of the state's 5,000,000 kg annual commercial fish catch is considered "rough fish" (e.g. carp and bullheads) and is shipped out of state (Floyd Hennagir, personal communication). Virtually all of the commercial fish products consumed in the state must be imported. Nationally, fish products constitute the second largest U.S. import in dollars, behind petroleum products (1). With a decline in natural stocks and commercial fisheries because of factors such as overfishing and pollution, there is a increasing need to look for new sources of fishery products.

Minnesota's vast water resources provide great potential for aquacultural development. However, the biological, technical and economic aspects of fish farming must be studied and evaluated before fish farming can become widely practiced in the state.

This paper describes a fish farming research and extension program conducted from 1979 to 1982 through Wright County Community Action of Waverly, Minnesota. Project objectives were to assist farmers with stocking and raising fish in farm ponds, to monitor fish growth and yields, and to evaluate different management techniques for family and commercial use in the state.

MATERIALS AND METHODS

Fish stocking and management. Fish were stocked into 57 privately owned farm ponds located in seven counties in central Minnesota during the three year project. Study ponds ranged in size from 0.02 to 2.0 ha (X = 0.12 ha), and in depth from 0.6 to 5.4 m (X = 1.8 m). Ponds were sampled prior to stocking to determine the presence of wild fish; ponds found to contain wild fish (excluding minnows) were not used in the study.

Six species of fish were stocked into study ponds. Channel catfish (Ictalurus punctatus), largemouth bass (Micropterus salmoides), yellow bullheads (I. natalis) and rainbow trout (Salmo gairdneri) fingerlings were purchased from private hatcheries in Minnesota, Iowa and Wisconsin. Stunted bluegill sunfish (Lepomis macrochirus) and black crappies (Pomoxis nigromaculatus) were obtained with traps and seines from overcrowded public lakes in the Wright County area under a special research permit from the DNR. Some ponds were stocked with only one species of fish (monoculture), while in other ponds two or more species were stocked (polyculture).

Pond management guidelines were formulated by pond owners and project staff. Warm-water fish species (catfish, bluegill, bass, crappies and bullhead) were stocked into standing water ponds at densities ranging from 16 to 600 fish per hectare. In several ponds catfish and bluegills were raised in floating cages one cubic meter in size. Stocking densities ranged from 80 to 240 bluegills or 200 to 1000 catfish per cage. The cold-water species, trout, was stocked into ponds with a constant flow of water from a spring or well. Trout stocking densities were based on the volume of water flow, ranging from 1 to 4 fish/liters per second. Fish stocked at higher densities received a pelleted catfish or trout ration, while supplemental feeds were not used at low stocking densities (Table 1). The amount of feed used was 3 percent of the estimated total weight of fish in the pond.
Pond owners and project staff recorded the number and weight of fish at stocking and harvest, weekly water temperatures and dissolved oxygen levels, weight of feed used, and amount of time and money spent on pond management. These data were used to analyze and evaluate the various production methods tested.

Fish harvests and yields. Warm-water fish were stocked in May and June and harvested between September and November. Except where aeration was used to prevent winterkill, total fish harvests were attempted after one growing season in warm-water ponds. In cold-water ponds trout were stocked in the spring or fall. Selective harvesting, removing only fish larger than a given size, began after three months and continued throughout the following year.

Fish were harvested with seines, hoop nets, trap nets, gill nets, lift nets, set lines, and hook and line. The efficiencies of different harvest methods were compared based on yields in ponds where total harvests were attempted after one season. Yields from ponds with low survival due to factors cited in the discussion have not been included in the analysis of harvest efficiency.

The results presented for fish growth and yields represent an average of production values from all ponds after a single growing season. The figures on trout growth are based on the average weight of fish sampled after one season, even though not all fish were harvested at that time. Bass and bullhead have been excluded from this analysis since a very limited number of trials were conducted with these species, and bass were not harvested until after a second growing season. A complete tabulation of yields for all ponds is presented in the project’s final report (4).

Production costs. Production costs for catfish, bluegills and trout were calculated based on average costs and yields obtained from ponds where 50 percent or more of the fish were recovered at harvest. Crappies are excluded from this analysis because of low recovery rates at harvest. Documented costs included the price and delivery charge for a private fish hatchery license, rental charges for equipment based on cooperative use through a private fish hatchery, rental charges for equipment based on cooperative use through a fish farmers association, electrical costs to run pumps and aeration, and labor costs for managing and harvesting fish ponds. Comparison of live weight and dressed weight of fish is based on a dress-out percentage of 75% for trout and 60% for catfish.

RESULTS AND DISCUSSION

Growth and yields. Good fish growth and survival were observed for single season production in ponds as small as 0.04 ha averaging 0.9 m or more in depth. Trout and catfish demonstrated the best growth, with a 483 percent and 280 percent increase in weight, respectively, after one growing season (Table 2).

Catfish and trout growth rates were higher with supplemental feeding than without feeding. Conversely, the growth rates for bluegills and crappies were higher without feeding (Figure 1). These differences could reflect the different species ability to adapt to supplemental feeds. The hatchery-reared species, catfish and trout, were accustomed to supplemental feeds and readily accepted the pellets, while the fish obtained from the wild, bluegills and crappies, did not. These differences could also be attributed to hatchery selection for desirable characteristics (5).

Total yields of fish were generally higher in ponds with supplemental feeding than without feeding, and higher in polyculture than monoculture (Table 3). Higher yields reflect not only growth rates but also higher stocking densities used in ponds with feeding and polyculture. Rainbow trout produced the highest yields (880 kg/ha). High trout stocking densities were possible with the constant supply of fresh water in these ponds. Since trout were not completely harvested at one time, total production was much higher than observed yields. The highest yields among warm water species were obtained with bluegills (119 kg/ha) in ponds without feeding, and catfish (254 kg/ha) in ponds with feeding.

While these yields are encouraging in Minnesota, where little work has been done with pond fish culture, they appear low when compared to production on commercial fish farms in the South, where yields over 1500 kg/ha are common (5, 6). Lower yields in Minnesota can be attributed to a shorter growing season resulting in smaller fish at harvest. Also, overall recovery of fish was poor; harvests averaged less than 50% of the number of fish stocked.

Poor fish survival was one cause of low recovery at harvest. Improper pond construction or poor management reduced fish survival through 1) flooding, which allowed fish to escape, 2) predation competition from wild fish, 3) disease, or 4) summer-kills or winter-kills from low oxygen levels.

Low recovery also resulted from the use of inefficient harvesting techniques. Most study ponds had not been designed for

<table>
<thead>
<tr>
<th>Species</th>
<th>Stocking weight (g)</th>
<th>Harvest weight (g)</th>
<th>Increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>Catfish</td>
<td>50</td>
<td>35-85</td>
<td>190</td>
</tr>
<tr>
<td>Bluegill</td>
<td>65</td>
<td>30-70</td>
<td>120</td>
</tr>
<tr>
<td>Crappie</td>
<td>80</td>
<td>55-65</td>
<td>155</td>
</tr>
<tr>
<td>Trout</td>
<td>30</td>
<td>30-55</td>
<td>175</td>
</tr>
</tbody>
</table>

The Minnesota Academy of Science
fish farming and were therefore difficult to harvest. The use of drainable ponds could have facilitated and improved fish recovery (7,8).

The efficiency of the harvest methods tested varied with species (Figure 2) and pond designs. Seining was effective for all species in ponds that had a smooth bottom and were not wider or deeper than the seine (4 m by 33 m). Fish traps and nets were used in ponds when seining proved ineffective. Bluegills and crappies were captured with hoop nets and trap nets. Catfish could not be captured with hoop nets, trap nets, gill nets, or lift nets. Some fish were caught with hook and line, but this could only be considered a technique for sampling rather than complete harvest.

Harvest efficiency was maximized with the use of cages, each of which could be completely harvested by two people in less than one hour. Good catfish growth and survival was observed in cages, and yields of 45 kg/m² were obtained in one growing season. Slower growth and higher mortality rates of bluegills were observed with yields averaging 11 kg/m². This appeared to result from aggressive territorial behavior of caged bluegills which prevented some fish access to the feed. Higher stocking densities in cages could have inhibited this behavior, as has been demonstrated for catfish (9).

Acceptability and profitability. Pond owners considered the majority of fish harvested after one season to be of acceptable size for home consumption. However, most fish were too small for commercial sale, where the minimum desired size is 175 to 225 g for panfish (bluegills and crappies) and 225 to 335 g for catfish and trout (3).

With few exceptions, owners evaluated the flavor and texture of pond-raised fish as good to excellent. Off-flavors were noted in several cases where fish were harvested from ponds with abundant weed growth. When this occurred owners postponed harvests for several weeks into the fall or held the live fish in fresh flowing water for several days prior to cleaning. Both techniques were effective for removing off-flavors from the fish flesh.

Trout was the most economical species cultured in this study (Table 4). Lower production costs for trout were possible because of the lower price of fingerlings (Figure 3) and better fish growth due to the longer growing season for cold water species. Current retail prices for trout range from $6.50 to $11.00/kg (dressed weight). Production costs for trout based on a 10 month growing season ranged from $3.00 to $8.00/kg, dressed weight, indicating a good potential for commercial culture of trout in Minnesota.

Current retail prices for crappies and catfish in Minnesota range from $6.50 to $13.00/kg (dressed weight), depending on the season and availability. Retail prices for bluegill are not available. In the present study, the cost of producing catfish for home use was within the range of current retail prices, but commercial production costs were not. This indicates that farmers can economically raise warm-water fish for home consumption but not for commercial sale.

Table 3. Average fish yields in study ponds after one growing season.

<table>
<thead>
<tr>
<th>Species</th>
<th>Yields (kg/ha) without feeding</th>
<th>Yields (kg/ha) with feeding</th>
</tr>
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<tr>
<td></td>
<td>Monoculture</td>
<td>Polyculture</td>
</tr>
<tr>
<td>Catfish</td>
<td>34 (114)³</td>
<td>178</td>
</tr>
<tr>
<td>Bluegill</td>
<td>121</td>
<td>119 (120)</td>
</tr>
<tr>
<td>Crappie</td>
<td>114</td>
<td>1 (120)</td>
</tr>
<tr>
<td>Trout</td>
<td>114</td>
<td></td>
</tr>
</tbody>
</table>

³ parenthesis indicates total yields of all species in the pond
Journal of, V. Iume Forty-nine, No. 1, 1983/84

Figure 1. Relative weight gain (harvest weight/stocking weight) in grams for different fish species in study ponds after one growing season of 3 to 5 months, based on the culture method used.

Figure 2. Average recovery (number of fish harvested/number of fish stocked) of different fish species in study ponds after one growing season of 3 to 5 months, based on the harvest method used.

While trout appears to be most suited to commercial culture, several factors could restrict its widespread application in Minnesota. There are a limited number of sites with cold flowing water available, and production costs would increase substantially if constant pumping of water was required. Also, the rising cost of ingredients in the high protein feed required by trout may reduce profitability in the future.

Warm-water fish culture could have wide application in Minnesota because of the many farm ponds and pond sites available. High production costs for warm-water species could be reduced in several ways: 1) establishing local hatcheries to lower fingerling costs, 2) using ponds designed for fish farming to enable efficient harvest and higher yields, 3) raising fish for two years with winter aeration instead of one year to produce larger fish. However, further studies are needed to assess the costs and yields of a two-year production system.

CONCLUSIONS

Substantial differences in fish growth and yields were found among ponds in this study (Table 2). Since the project was conducted under field conditions rather than controlled experimental conditions, replicated trials were not possible. Location, water quality and management varied between ponds. Therefore, the results of this study need to be further tested and refined before
Table 4. Average production costs for fish reared in study ponds.

<table>
<thead>
<tr>
<th>Species</th>
<th>Home use</th>
<th>Commercial use</th>
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<tbody>
<tr>
<td>Catfish</td>
<td>6.04</td>
<td>9.42</td>
</tr>
<tr>
<td>Bluegill</td>
<td>4.40</td>
<td>5.47</td>
</tr>
<tr>
<td>Trout</td>
<td>3.87</td>
<td>9.82</td>
</tr>
<tr>
<td>Trout</td>
<td>2.09</td>
<td>5.18</td>
</tr>
</tbody>
</table>

- Based on 3 to 5 month growing season, similar to warm water species.
- Based on a 10 month growing season.
- The cost of production for "home use" does not include the cost of labor, while commercial production costs include a charge for labor.

ACKNOWLEDGMENTS

We would like to thank the following organizations which provided funding for the project: Minnesota Governor's Council on Rural Development, Wright County Community Action, Twin Cities Presbytery of the Presbyterian Church, Otto Bremer Foundation and Minnesota Green Thumb. An advisory committee comprising representatives of the Soil Conservation Service, University of Minnesota, Department of Natural Resources, Department of Agriculture, and the Agricultural Extension Service provided valuable assistance throughout the project. Special thanks are due to Vernon Hedner and Gregory Vaut for their contributions and support, and especially to the fish farmers who participated in the program.

REFERENCES

Identification and Characterization of Three Glacial Tills in Kandiyohi County, Minnesota

ALLAN G. GIE N C K E,* RIC H ARD O. PAU L S O N,** AND J AM ES R. CRU M ***

ABSTRACT — During the course of the Kandiyohi Co., Minnesota, soil survey, three different glacial tills were recognized and separated from what was formerly thought to be one homogeneous glacial till. The first glacial till is from the Des Moines Lobe ice advance. It has a fine-loamy particle size, friable consistency, and appreciable amounts of Cretaceous shale fragments. The oven-dry bulk density ranges from 1.3 to 1.5 g/cc. The second glacial till is from the Wadena Lobe ice advance. It has a coarse-loamy particle size, friable consistency, oven-dry bulk density of 1.5 to 1.7 g/cc, and small amounts of Cretaceous shale fragments. The third glacial till is thought to be pre-Wisconsin. Evidence suggests this till was buried and later thrust to the surface during the advance of the Wisconsin Age ice lobes. This “older” till, tentatively named “Kandiyohi”, has a fine particle size, firm or very firm consistency, and appreciable amounts of fine, rounded shale fragments. The oven-dry bulk density ranges from 1.7 to 2.0 g/cc. The inherent properties of the soils formed in each glacial till affect use and management. Therefore, a different catena of soils is mapped on each of the three glacial tills.

INTRODUCTION

During the first few years of a soil survey, the properties of many soils are described and measured on samples from the modal sites to provide a basis for the mapping-unit legend to be used in the survey area. In Kandiyohi county (Fig. 1), a detailed study of the stratigraphy and range of characteristics of glacial till was incorporated into this investigative part of the survey to determine if major geomorphic areas consisted of one homogeneous glacial till, as existing literature suggested, or if there were contrasting tills within these geomorphic areas.

The lowest lying (elevation ~ 1100 feet) geomorphic area in this study was the Olivia till plain (Fig. 2) formed by the Des Moines Lobe advance during the Wisconsin Age (1). This till plain is nearly level to gently undulating; local relief is commonly 2 to 8 feet. The next higher (= 1200 feet) geomorphic area in this study was the Alexandria Moraine Complex (Fig. 2), formed by an advance of the Wadena Lobe during the Wisconsin Age (2,3,4). This terminal moraine is typically rolling to steep with a local relief of 10 to 40 feet. The highest lying (= 1250 feet) geomorphic area is a part of the Alexandria Moraine Complex (Fig. 2). It is gently undulating to hilly with local relief of 5 to 25 feet. Its mode of formation is not clearly understood. Evidence suggests this glacial till is much older than the Wisconsin Age. Deep borings suggest this till was buried and later thrust to the surface by Wisconsin Age ice advance (5). This till is proposed as the “Kandiyohi” till.

METHODS AND MATERIALS

When characterizing soils, the most commonly-used measures are: a) Particle-size Distribution (6), b) Organic Carbon, c) pH (6), d) Calcium Carbonate Equivalent, e) Bulk Density (6), f) Coarse-fragment Analysis, and g) Engineering Tests. (8).

* U.S. Dept. Agriculture, Soil Conservation Service, Willmar, Minn.
** U.S. Dept. Agriculture, Soil Conservation Service, St. Peter, Minn.
*** Dept. of Soil Science, University of Minnesota, St. Paul, Minn.

Figure 1. Location of Kandiyohi county within Minnesota.

Particle-size distribution, bulk density, course-fragment analysis, and engineering tests provided the best indication of differences between the glacial tills in Kandiyohi county and are discussed in this paper.

The engineering tests can be grouped into three general categories: (1) Consistency Tests and Indices (Liquid Limit and Plasticity Index), (2) Moisture-Density Tests (Maximum Density and Optimum Moisture Content), and (3) Engineering Classification (AASHTO Class, Group Index, and Unified Class) (Table 1).

The consistency tests correlate to the particle-size distribution
The samples analyzed from the three glacial tills in Kandiyohi county were collected from sites widely distributed within each of the geomorphic areas (Fig. 2) to provide a range in characteristics. The characterization analyses were done by the Soil Survey Laboratory, Minnesota Agricultural Experiment Station, St. Paul, Minnesota. The engineering tests were performed by the Minnesota Department of Transportation, St. Paul, Minnesota.

**GEOGRAPHIC AREAS**

**Olivia Till Plain.** The Des Moines Lobe till in this geomorphic area is characterized by a fine-loamy particle size (Fig. 3), friable consistency, and appreciable amounts of platy Cretaceous shale fragments. An average of 10 till samples shows the texture to be loam with about 40 percent sand, 36 percent silt, and 24 percent clay (Fig. 3). The bulk density of oven-dry samples above a depth of 60 inches ranged from 1.3 to 1.5 g/cc. Engineering test results are summarized in Table 1.

These data indicate an intermediate engineering quality compared to the Alexandria moraine till and the Kandiyohi till. The real value of these data, in this study, is in observing the separation of the three tills. Engineering properties, and therefore the interpretations applied to soils, are in many cases used to define soil series. The soils developed on these glacial tills behave differently and have the accompanying different interpretations for agricultural drainage, septic tank adsorption fields, crop suitability, building site development, and other components of Soil Survey Reports.

**Alexandria Moraine Complex (Wadena Till).** The Wadena Lobe till in this geomorphic area has a coarse-loamy particle size (Fig. 3). The till is friable to very friable and has very few (if any) fragments of Cretaceous shale. An analysis of 10 till samples shows the texture to be fine sandy loam with about 59 percent sand, 28 percent silt, and 13 percent clay (Fig. 3). The oven-dry bulk densities above a depth of 60 inches ranged from 1.5 to 1.7 g/cc. Engineering test data indicate that these soils are rather well suited for use as construction material (Table 1). One unusual feature of this till is that it has relict mottles in a random and unpredictable pattern that do not reflect a present-day moisture regime.

**Table 1. Engineering test data for samples taken from the type location of each till.** These analyses run by the Minnesota Department of Transportation.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Alexandria Moraine Till</th>
<th>Des Moines Lobe Till</th>
<th>Kandiyohi Till</th>
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<tbody>
<tr>
<td>Liquid Limit</td>
<td>27</td>
<td>38</td>
<td>59</td>
</tr>
<tr>
<td>Plasticity Index</td>
<td>6</td>
<td>15</td>
<td>28</td>
</tr>
<tr>
<td>AASHTO Class</td>
<td>A-4</td>
<td>A-6</td>
<td>A-7</td>
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The Minnesota Academy of Science
Alexandria Moraine Complex (Kandiyohi Till). The Kandiyohi till is characterized by a fine-clayey particle size (Fig. 3). The consistency is firm to very firm, and there are appreciable amounts of fine rounded Cretaceous shale fragments. An analysis of 10 till samples shows the average texture to be clay loam with about 24 percent sand, 39 percent silt, and 37 percent clay (Fig. 3). Oven-dry bulk densities from samples above 60 inches ranged from 1.7 to 2.0 g/cc. Engineering test data indicate that this material is very poor for use as a construction material (Table 1). The high clay content and high bulk densities make this a very difficult material to work with.

DISCUSSION

Tills and Kindred Soils. In a soil survey report, individual soils are separated by mapping different soil series to allow for differing interpretations for use and management. Because the inherent physical properties of each till unit are different, it was necessary to identify and map a separate catena of soil series for each glacial till. Most of the soils formed in the Des Moines Lobe till have a fine-loamy particle size. These soils are in the Swanlake, Ves, Lester, Nicollet, Normania, Canisteo and Webster series. Most of the soils formed in Wadena Lobe till have a coarse-loamy particle size. These soils are in the Sunburg, Waderoll, Koronis and Grovecity series. In the Kandiyohi till, most of the soils have a fine particle size. These soils are in the Arkon, Guckeen, Kilkenny, Marna and Brownton series.

Soil science and soil survey mapping are closely related to geomorphology and geology. To better understand variations in soil series, one must understand their differences in geological formation. However, it is not within the scope of, nor intent of, this report to present the complete geomorphology of these tills. The authors have identified and characterized differences in the nature and properties of the three major glacial till bodies in Kandiyohi County, based on Soil Survey information and engineering test data. Many questions still exist as to the stratigraphic relationship of these three tills. Is the Kandiyohi till a "pre-Wisconsin" till? Was the Alexandria Moraine covered by ice from the Des Moines Lobe? These questions merit further study. Meanwhile, differentiation of "Kandiyohi" till is a significant step toward greater understanding of the geomorphology and geology of this part of the glaciated area of Minnesota.

REFERENCES
SPECIAL REPORT

A Progress Report of the Cedar Creek Natural History Area

DAVID F. PARMELEE

David F. Parmelee, Professor and Program Director, Field Biology Program, University of Minnesota, has directed the Cedar Creek Natural History Area and the Lake Itasca Forestry and Biological Station since 1970. He received a B.A. from Lawrence University, M.S. at the University of Michigan and a Ph.D. from the University of Oklahoma.

The Cedar Creek Natural History Area is a 2,185 hectare research site in Anoka and Isanti Counties near East Bethel, Minnesota. It is especially valuable not only because of its proximity to the Twin Cities but also because it contains elements of prairie and boreal vegetation in addition to predominately eastern deciduous types. Cedar Creek has a variety of soil types, and important underground aquifer, and oak savannas maintained through controlled burning. The area serves both as a "living museum" and an important site for ongoing scientific research.

Dr. William H. Marshall, director of the Cedar Creek Natural History Area from 1961 to 1970, wrote two progress reports (Marshall, 1964, 1968) for the Minnesota Academy of Science. Although many aspects of the Cedar Creek program have changed little since Marshall’s time, a number of developments in recent years almost certainly will have lasting influences. The purpose of this report is to inform Academy members and other interested persons of these activities.

Cedar Creek Advisory Committee

According to Marshall (1968), the Cedar Creek Advisory Committee, chaired at the time by Dr. Donald B. Lawrence, consisted of representatives from various departments of the University of Minnesota and three Academy members — Drs. William Downing, David Grether, and Dale Chelberg. This arrangement was adopted and used with slight modification by the current administration since 1970. The only reorganization of consequence had its beginning in February 1977 when Chairman L. Daniel Frenzel commissioned an ad hoc committee comprising Drs. Harrison B. Tordoff and David Grigal to develop guidelines for selection and rotation of the Advisory Committee chairperson and members.

The guidelines, as set forth in the November 1977 minutes are as follows:

The Cedar Creek Advisory Committee will be comprised of 12 members. Eight members represent the university departments whose research interests are tied closely to Cedar Creek (Botany, Ecology and Behavioral Biology, Entomology, Fisheries and Wildlife, Forestry, Bell Museum of Natural History, Soils, Field Biology Program and Zoology), three represent the Minnesota Academy of Science, and one represents the staff working at Cedar Creek.

New members of the committee shall serve 4-year terms. Each year three members of the committee will be replaced with others from the departments they represented. It was recommended that only one representative from the Minnesota Academy of Science be replaced in any year.

The three replacement members each year will be suggested by a nominating committee made up of existing Cedar Creek Advisory Committee members, excepting that representatives from the Minnesota Academy of Sciences be appointed by the Academy. The suggested nominees will be presented to the Dean of the Graduate School for his approval and appointment.

The chairman of the committee will serve a two-year term and will be nominated and elected by the advisory committee membership.

The reorganization proved fruitful in many respects but it also had shortcomings. Departments often were tardy in appointing replacements, and meeting attendance was sluggish at best. In order to improve Academy attendance, former Academy President Wayne C. Wolsey met with the Academy’s Board of Directors at its March 1982 meeting and was instrumental in passing a number of important resolutions:

Each year one new member shall be appointed to a three year term on the Cedar Creek Advisory Committee. Primary consideration should be given to candidates who exhibit a professional interest in Cedar Creek. The committee members should attend all meetings or arrange for a substitute from an alternate list. A copy of all minutes shall be sent to the Academy office and to the President and President-Elect of the Academy.

The committee representatives shall report at least annually to the Board of Directors.

Currently the Cedar Creek Advisory Committee has three primary members and three alternate members from the Academy. A frequently voiced concern relating to membership is that state educational institutions, in addition to the University of Minnesota, be adequately represented on the Cedar Creek Advisory Committee. The Academy should be cognizant of these concerns because only it can appoint such members under existing guidelines.

As of March 1983, the Cedar Creek Advisory Committee consisted of the following:

ACADEMY REPRESENTATIVES

Primary Members
Dr. L. Daniel Frenzel — University of Minnesota
*Mr. William V. Lacina — Blaine Senior High School
Dr. Richard Mierotto — College of St. Thomas
Alternate Members
Dr. Mark Davis — Macalester College

The Minnesota Academy of Science
Educational and scientific groups, a designated Nature Trail is provided for demonstrations and conducts tours in the field. Since it is not always possible to obtain qualified TA's, we are initiating an annual orientation workshop at the Laboratory. It is our hope that prospective group leaders will attend the workshop in order to qualify as guides in conducting their own tours.

Over the years our staff and students have willingly assisted many visiting groups. Since most visitors are intensely interested in the radio-telemetry program, our electronics personnel deserve special praise for their patience and assistance.

The only area on Cedar Creek available to the public without permit is the Nature Trail located near Fish Lake. Inasmuch as Professor Marshall was instrumental in its planning and development, we think it highly appropriate to call it the "Marshall Nature Trail." Plans are underway to obtain official recognition for the naming of this trail and other trails and historic sites at Cedar Creek.

Land Acquisition

Most of Cedar Creek's 5300 acres (2185 hectares) were acquired through gift or purchase during the early days of its history when land was relatively obtainable and inexpensive. According to Marshall (1968) the last major purchases were made in 1967 for lands adjacent to Fish Lake, including a public nature trail. No further land acquisitions have been made since 1967, even though several 40- to 80-acre plots would be desirable to fill out conspicuous indentations in Cedar Creek's Western edge.

Public sentiment and recent housing developments do not encourage extensive expansion of Cedar Creek beyond its borders. Considering the many acres that already buffer the area's most crucial habitats, we have noted little enthusiasm for additional acquisitions at current prices. Marshall and others had the keen foresight to obtain as much land as they did during a critical period of the area's development.

Experimental Ecological Reserves

One of the more important annual meetings for field station directors is the Organization of Biological Field Stations (OBFS) which began in 1968 at the Cedar Creek Natural History Area. The meeting is held each September at a different station, thus affording directors the opportunity to visit a variety of sites. A highlight of the meeting is a talk and discussion by representatives of the National Science Foundation (NSF) on federal funding of research at field stations.

At the September, 1971 OBFS meeting, NSF representatives stated emphatically that research funds earmarked for stations likely would be limited to those sites that could clearly demonstrate ongoing research coupled with strong institutional support; those showing only promise and unfulfilled potential would receive little funding. NSF then turned to The Institute of Ecology (TIE) for assistance in determining which of the many field sites qualified. From this beginning emerged the concept of a national network of Experimental Ecological Reserves (EER).

A study of the feasibility of a system of Experimental Ecological Reserves was supported by a grant from NSF's Biological Research Resources Program. Project meetings followed, and in time those sites wishing to enter the designation competition were asked to submit lengthy and detailed reports on all aspects of station activity, including past and current budgetary accounting. The Field Biology Program put forth its best effort in behalf of the University's Cedar Creek and Lake Itasca Forestry and Biological stations.

The peer reviews by TIE were thorough. Some of the toughest questions dealt with experimental manipulation of land within a natural area or park, such as Itasca State Park. The Itasca problem was quickly resolved when it was demonstrated that the state park already had developed a model plan that included five major classifications of land usage ranging from highly manipulative to unapproachable sanctuary types. Although Cedar Creek had many sanctuary-type uplands and marshes as well as tracts being converted to a natural state, considerable areas were also being manipulated through controlled burning and farming. That research was an important component of Cedar Creek from the time of its inception was clearly demonstrable through its research record dating back to Ray Linde's classic studies at Cedar Bog Lake.
classic studies at Cedar Bog Lake.

The site evaluation scheme used by TIE stressed (1) site quality, including representativeness, size, and control heterogeneity, and (2) research activities, including historical data, quality and intensity, publication record and staff capabilities. Also weighed heavily were logistics and support, including site integration, laboratories and equipment, resident research staff, technical staff, accessibility and utilities, services, housing and amenities, and scientific interchange. Consideration was also given ancillary benefits, including training programs.

The complete TIE report on Experimental Ecological Reserves may be obtained from the Superintendent of Documents, U.S. Government Printing Office. With respect to the evaluations, a score of 70 percent or greater indicated that the site being considered met the criteria for designation as an EER. A score of less than 70 percent indicated that the site had good, some, or very limited potential. On the recommendation of TIE, 67 sites spanning the breadth of the nation were designated EERs in the initial network. Itasca scored very high because of its unique setting and habitats as well as its long history and institutional support. Cedar Creek scored somewhat lower, although still over 70 percent. Three additional Minnesota sites, Cuffeony, Marcell and Pike Bay Experimental Forests, scored under 70 percent but nevertheless were recognized for their high potential.

A number of potential benefits were anticipated from the EER network. The TIE report noted that a “comprehensive EER network will provide an ecologically-sound framework within which to test scientific hypotheses and will offer the capability to examine environmental impacts in many ecosystems.” The report also stated that “experimental studies and monitoring at EER sites will provide the baseline data for a framework within which each ecosystem’s responses can be evaluated” and that “the enhanced data base and interaction of scientists using the site will be conducive to development of collaborative and integrated research efforts.” According to the TIE report, “The EER network will guide the investment of limited financial resources in physical facilities and technical support skills and will encourage their effective use.”

This last statement has special significance with respect to federal funding. The EER designation merely guides NSF in distributing its limited resources. It does not mean, as some thought might that an EER is automatically targeted for federal support. The EER designation does give the site very good credentials.

Appointment Of Associate Director

The Field Biology Program was established in 1966 and incorporated not only the Cedar Creek Natural History Area but also the Biology Session at the University of Minnesota Forestry and Biological Station at Lake Itasca, Minnesota. Although there are many advantages in having the two field stations under one office, there are certain disadvantages, notably that the program director of the Field Biology Program cannot reside in two places at once. Since it imperative that the program director be at the Itasca station during the busy summer training period, the Cedar Creek station is left without adequate supervision during its most important season.

In the fall of 1980, Dr. G. David Tilman of the Department of Ecology and Behavioral Biology was appointed Associate Director of the Cedar Creek Natural History Area. His duties include selecting and chairing an outside advisory panel and extending the computer-based system for managing data from the Cedar Creek research. To qualify as a regional or national facility, a field site such as Cedar Creek should be advised and evaluated on a regular basis by an unbiased panel of scientists outside Minnesota—an important consideration not to be taken lightly in view of National Science Foundation guidelines. The outside advisory panel for Cedar Creek currently includes Dr. Gene Likens of Cornell University, and Dr. James McMahon of Utah State University. A third member is to be selected.

Judging by what transpires at the annual meeting of field station directors these days, probably no greater concern exists than that dealing with the management of field data. Record managing at most field stations is archaic; Cedar Creek is no exception. With incredible advancements in computers and recording devices in the past decade, there is hope that our new programs will speed the modernization of the system. Already one of our new programs described below under Long-Term Ecological Research is accumulating vast amounts of field data and storing them in University computer banks for safe keeping and convenient retrieval. An LTER is committed to good management of its data. Other investigators will be encouraged to manage their Cedar Creek data equally well.

Long Term Ecological Research

A sibling association of the EERs is the Long-Term Ecological Research (LTER) by the Division of Environmental Biology of NSF. The pilot program, which was first open to national competition in 1979, required that the following research efforts be addressed: (1) pattern and control of primary production; (2) spatial and temporal distribution of populations selected to represent trophic structure; (3) pattern and control of organic matter accumulation in surface layers and sediments; (4) patterns of inorganic inputs and movements of nutrients through soils, groundwater, and surface waters; (5) patterns and frequency of disturbance to the research site. Since LTER sites are considered regional and national facilities, they are committed to collaborative research with scientists from outside as well as within the home institution.

A cadre of scientists at the University of Minnesota entered the competition and chose Cedar Creek rather than Itasca as their home base. Cedar Creek had a variety of interesting soil types and its proximity to the Twin Cities campus provided many advantages. Moreover, former studies had provided valuable baseline data. Although ecosystem ecology was the mainspring of the LTER program and the University clearly lacked in ecosystem specialists, enough talent in ecology and related areas was available to win recognition with a revised second proposal. In December 1981, Cedar Creek was designated an LTER—one of only 11 in the nation—and shortly thereafter awarded a five year, $1.3 million subvention.

Drs. G. David Tilman and John R. Tester of the Department of Ecology and Behavioral Biology are the Principal Investigators of the Cedar Creek LTER project. Other LTER investigators are listed below under Current Major Research Projects. According to Tilman, the research is an attempt to understand succession through a synthesis of population, community, and ecosystem perspectives combined with long-term experimental manipulations of natural communities. The research includes detailed observations of large plots and experimental manipulations of smaller plots. The manipulations include: (1) fertilization with different levels of nitrogen with all other elements supplied in excess; (2) fertilization with each of 6 nutrient elements applied singly; (3) disturbance-nitrogen in-
teractions; (4) gopher removal; (5) deer removal; (6) insect removal; (7) fire. Of primary interest are the mechanisms whereby soil processes, interspecific plant competition, and herbivores influence the diversity and species competition of natural plant communities.

LTER at Cedar Creek began in the spring of 1982 and was in full swing by summer of the same year. Field season site usage increased from about 10 full-time individuals to over 50 individuals. Among the participants were many undergraduate and graduate students chosen on a competitive basis from the University of Minnesota and other educational institutions. As it turned out, most of the undergraduate student employees for the 1982 season came from schools other than the University.

The LTER also gave Cedar Creek its first and long sought after Resident Ecologist. The position was advertised nationally and, following a critical review of several hundred applicants, Dr. Mark Stillwell from Ft. Collins, Colorado, was chosen for the position on a post-doctoral appointment. Dr. Stillwell's background and expertise in nitrogen cycles and ecosystem ecology adds a new dimension to Cedar Creek's research potential.

The position of Resident Ecologist should not be confused with that of Resident Manager. The latter is supervised and budgeted by the Physical Plant Operations of the University of Minnesota. Mr. Alvar Peterson was Cedar Creek's former Resident Manager. After many distinguished years of service, he retired on 4 February 1982. The position was filled on 1 April 1982 by Mr. David Bosanko, former Resident Biologist of the University's Lake Itasca Forestry and Biological Station.

Current Major Research Projects

Research projects at Cedar Creek during the 1970's are listed by author, title, and abstract in the Cedar Creek Annual Reports that are prepared and filed by the Field Biology Program. The reports and updated lists of publications are too cumbersome to include here; however, a brief listing of on-site projects active or pending for 1982-83 follows.

WATERFOWL BEHAVIOR AND MATING SYSTEMS (NSF renewal pending)
Frank McKinney, Professor, Ecology and Behavioral Biology; Jeffrey Burns, Post-Doctoral Researcher

INSECT HERBIVORY AND ASSOCIATIONAL RESISTANCE IN NATIVE PLANTS (NSF)
Patrice A. Morrow, Associate Professor, Ecology and Behavioral Biology; David Tonkyn, Post-Doctoral Researcher

MICRO AND MACRO VIEWS OF SUCCESSION, PRODUCTIVITY, AND DYNAMICS IN TEMperate ECOSYSTEMS (NSF, Long-Term Ecological Research)
Donald Alstad, Assistant Professor, Ecology and Behavioral Biology; David F. Grigal, Professor, Soil Science; Patrice Morrow, Associate Professor, Ecology and Behavioral Biology; Donald B. Siniff, Professor, Ecology and Behavioral Biology (Principal Investigator); G. David Tillman, Associate Professor, Botany, Michigan State University.

THE ROLE OF ROOT DYNAMICS IN OLD FIELD SUCCESSION (funded through U.M. Agricultural Experiment Station)
David F. Grigal, Professor, Soil Science; Robert McKane, Graduate Student, Soil Science

CONTROLS OF PRIMARY PRODUCTIVITY IN FORESTS AND FIELDS: THE ROLE OF SOIL CHARACTERISTICS AND LIGHT ATTENUATION EFFICIENCY (funded through U.M. Agricultural Experiment Station)
David F. Grigal, Professor, Soil Science; Mike Norland, Graduate Student, Soil Science
FORAGING DYNAMICS, HABITAT USE AND SOCIAL SYSTEMS IN GEOMYS BURSARIUS (GOPHERS) (NSF proposal pending)
James O. Reichman, Assistant Professor, Division of Biology, Kansas State University; John R. Tester, Professor, Ecology and Behavioral Biology; Kathleen Zinnel, Graduate Student, Ecology and Behavioral Biology

THE ROLE OF ABOVE AND BELOW GROUND INSECT AND MAMMALIAN HERBIVORES IN DETERMINING PLANT COMMUNITY STRUCTURE (partial NSF support via LTER)
Nancy J. Huntly, Post-Doctoral Researcher, Field Biology Program

RESOURCE ALLOCATION AND THE LIFE HISTORIES OF PERENNIAL PLANTS (partial NSF support via LTER project)
Richard S. Inouye, Post-Doctoral Researcher, Field Biology Program

DEER HERBIVORY AND THE INVASION OF OLD FIELDS BY WOODY PLANTS (partial NSF support via LTER project)
Richard Inouye, Post-Doctoral Researcher, Field Biology Program; Taber Allison, Graduate Student, Ecology and Behavioral Biology

NITROGEN CYCLES AND SUCCESSION: THE ROLE OF LITTER DECOMPOSITION AND MINERALIZATION PROCESSES (partial NSF support via LTER)
Mark Stillwell, Resident Ecologist (Post-Doctoral Researcher), Cedar Creek

Independent Graduate Student Research

EVOLUTION OF MONOEY, DIOECY, AND OUT-CROSSING IN GRASSES (Field Biology Program support)
Mark McKone, Graduate Student, Ecology and Behavioral Biology

COEVOLUTION IN A GUILD OF ANT-TENDED HERBIVORES (Field Biology Program support)
Jeffrey Brokaw, Graduate Student, Ecology and Behavioral Biology

EFFECTS OF DEER BROWSING ON TAXIS CANADENSIS (Field Biology Program support)
Taber Allison, Graduate Student, Ecology and Behavioral Biology

THE BEHAVIORAL ECOLOGY OF THE BLUE JAY, CYANOCITTA CRISTATA (Dayton-Wilke Fund)
William J. Hilton, Jr., Graduate Student, Clemson University

PLANT DYNAMICS IN EARLY SUCCESSION
Barbara Delaney, Graduate Student, Botany Department

INSECT DYNAMICS IN EARLY SUCCESSION
John Haarstad, Graduate Student, Entomology, Fisheries and Wildlife

Graduate Student Research Partially Supported by the Long-Term Ecological Research Project:

THE STRUCTURE OF INSECT COMMUNITIES IN OLD FIELDS
Rebecca Goldburg, Graduate Student, Ecology and Behavioral Biology

EVOLUTION OF HOST-PLANT CHOICE BY SPITTLEBUGS
William Goodman, Graduate Student, Ecology and Behavioral Biology

DYNAMICS OF RODENT POPULATIONS THROUGH SUCCESSION
(Pre-Doctoral Fellowship)
Susan Braun, Graduate Student, Bell Museum of Natural History

SEED RAIN, SEED BANKS AND THE ECOLOGY OF PLANT ESTABLISHMENT
Sara Webb, Graduate Student, Ecology and Behavioral Biology

HERBIVOROUS INSECT COMMUNITIES ON ARTEMESIA AND AMBROSIA AND EFFECTS OF CRYSOMELID BEETLE ON RHUS GLABRA
Sharon Strauss, Graduate Student, Ecology and Behavioral Biology

Field Assistants For Summer Research in 1982

The LTER employed two Botany MS students and two under-graduate biology majors and Morrow's NSF grant employed two undergraduate students full-time in 1982. In addition, the Field Biology Program employed 8 undergraduate students as full-time field technicians to assist with various aspects of the research projects listed above. Additional field assistants were obtained through the Comprehensive Employment Training Act (CETA) program, which provided 10 1/4-time students. The Youth Conservation Corps assisted with various aspects of the above research programs by providing a crew of 10 for two weeks.

In addition to a year-round staff, at least 10 faculty and visiting scientists, 5 post-doctoral researchers, 14 graduate students, and 24 full-time summer field assistants will be working at Cedar Creek during the summer of 1983. The greatly increased numbers and facility use have challenged the ability of Cedar Creek to provide scientists and students with adequate laboratory, office and housing accommodations. Although such activity was hardly unpredictable, it has been virtually impossible to obtain expanded facilities on promise of increased activity alone. Now that research is flourishing at Cedar Creek, there is a strong, proven case for expanded facilities.

The building program of the 1970's and that planned for the early 1980's are presented below.

Special Activities

The intent here is not to list the many important projects carried on at Cedar Creek during the 1970's, but to mention several that will likely influence many studies in the

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future. The following are listed chronologically with respect to completion dates, including some studies that were initiated before 1970.

1. A catalog of the flora of Cedar Creek by Moore (1973). This important long-term study contains 761 taxa of vascular plants based on 30 years of collecting and study by the author, a former scientist of the Department of Botany at the University.

2. A report on Cedar Creek soils by Grigal et al. (1974). In August 1972, a soil survey of Cedar Creek and adjacent areas was begun by the Minnesota Agricultural Experiment Station and the USDA Soil Conservation Service; the resulting report was both comprehensive and significant. Partial funding came from the Field Biology Program.

3. Vegetation mapping by Huempfner and Erickson (1975). As part of a dissertation study by Huempfner on winter foraging by ruffed grouse, financed largely by the Cedar Creek Radio Telemetry Program, a significant portion of Cedar Creek's vegetation was mapped in detail. Roughly one-fifth of Cedar Creek (545 hectares, 1,346 acres) was mapped by the authors, although only 250 hectares were used in the grouse study.

4. Land Management Report by Grigal et al. (1979). An ad hoc committee of the Cedar Creek Advisory Committee led by Dr. David Grigal developed a land management plan for the area with a number of important recommendations.

These included manipulations for replacement of unwanted smooth brome by native species; continuation of periodic abandonment of old fields to provide a series of tracts of different ages; protection of some old fields from unnecessary disturbance to allow natural succession; and continuation of the burning program for control and regeneration of certain plant species. Over the years Dr. Donald B. Lawrence has been especially active in control and regeneration manipulation.

5. Problem analysis and preliminary plan for expansion of the fire management unit by Irving (1980). For many years Dr. Frank Irving has planned, developed, and supervised the Cedar Creek burning program that not only maintains the oak-savannah habitats but also provides an important data base for future ecological studies.

6. Research policies of the Cedar Creek Natural History Area by Tilman (1983). Dr. G. David Tilman evaluated and revised the research policies of Cedar Creek following an exhaustive review by the Cedar Creek Advisory committee.

In addition to the above, current aerial photo prints (from infrared transparencies) of the Cedar Creek area were purchased in 1981 for use by all investigators at the Cedar Creek Laboratory. During the 1970's, Mr. John Haarstad built a sizable research insect collection which is housed in special cases at the Laboratory. Former plant collections from Cedar Creek are mostly housed in the herbarium at the University where they have been included in a computer-based collections system managed by Dr. Clifford Wetmore. A smaller collection of plants is housed at the Laboratory for on-site use by investigators.

Graduate Student Research Stipends

In 1981 the Field Biology Program sponsored a graduate student research program designed for Cedar Creek. Seven awards totaling $2,306 were given that year on a competitive basis with the hope that the seed money would help beginning graduate students initiate on-site research programs that could be funded later through other sources. The awards covered such expenses as field equipment, supplies, transportation, food, but not salaries or assistants. Free dormitory housing was provided for those who chose to reside at Cedar Creek.

An expanded program of awards began in 1982. Four graduate student research awards in amounts of up to $500 each were awarded for a total of $800. Graduate student summer research stipends of $1,500 each were awarded to three students whose work showed unusual promise. The newly established LTER program at Cedar Creek not only provides opportunities for participation to prospective students, but also will provide all investigators with detailed information on plant population dynamics, phenology and soils, insect and small mammal surveys, etc.

The Field Biology Program plans to continue the student programs whenever it can afford to do so. Numbers of recipients will vary from year to year, as almost certainly will the numbers and types of projects proposed or being carried out. The awards will be open to all qualified students on a competitive basis. Information concerning these awards may be obtained from the Field Biology Program Office.

Student awards other than those sponsored by the Field Biology Program are available from time to time. For example, in 1981, Dr. Donald B. Lawrence solicited proposals and awarded stipends for brome field conversions.

Friends Of Cedar Creek

When the Cedar Creek Advisory Committee was established, a Promotion and Fund Raising Subcommittee was also set up to raise funds. However, Marshall (1968) reported that this subcommittee had not been activated. The subcommittee was dormant during the 1970's as well, mostly because funds were sought from outside granting agencies.

Most of the funding for Cedar Creek was generated by the Radio-Telemetry Program through federal grants to Drs. John Tester and Donald Siniff, with lesser amounts being generated from federal research grants to Drs. Frank McKinney, Patrice Morrow, Philip Regal, Robert Taylor, and the author. Because of a foreseeable decline in state and federal grants, the Field Biology Program thought it advisable to initiate a "Friends of Cedar Creek" account through the University of Minnesota Foundation. This was set up in December 1980 following a gift of $632.04 from the late Ms. Edna May Carr.

Small donations have since accrued to this account. No funds have been withdrawn to date, and it is hoped that this modest start may be the beginning of a substantial endowment of the future.
Buildings

The Cedar Creek Advisory Committee reached a decision early in the 1970's concerning the rehabilitation of a number of vacated cabins and homes obtained through land acquisition. The Committee voted to dispose of all buildings that required extensive repair. Nearly all of the dwellings needed new wells and plumbing to meet the health standards set by the University's Department of Environmental Health and Safety. At the time Cedar Creek money was in such short supply that even those buildings believed to have had some marginal value were not salvaged; little by little they were destroyed or removed through contract arrangements supervised by the resident manager, Mr. Alvar Peterson. A few of the old buildings still survive; but two of them, the Corniea Cabin and Skogerboe Home, have been condemned recently by the University. The Norris Cabin near Cedar Bog Lake has been repaired for use as a summer dwelling only, though water has to be hauled in from the main laboratory.

Three year-round family homes at Cedar Creek are in good condition and are nearly always occupied. Faculty, staff, and students have priority for their use, but others may occupy them when they are vacant. Rental income goes to the University's Physical Plant Operations and is used for maintenance purposes.

The main building at Cedar Creek, often referred to as the Laboratory, is a 386.22 m² year-round facility that was financed in 1954 largely by a $75,000 grant from the Max C. Fleischmann Foundation of Nevada. For a number of years it was divided into a large assembly room with kitchenette, four offices, a four-bunk men's dormitory, a ten-bunk men's dormitory, bathroom facilities, and a two-bedroom family apartment that was sometimes used for offices and a conference room. This arrangement had its first significant change in 1978 when the Cedar Creek Advisory Committee voted to move the Radio-Telemetry Program from its old quarters in a 155.92 m² shop type building to the Laboratory.

Plans had been drawn previously for a separate Radio-Telemetry Program building that would have operated chiefly on solar energy. The State Legislature decided not to fund the special building but instead awarded $42,470 to rehabilitate the old telemetry quarters which had severe cooling and dust problems. However, when the University's Physical Planning Office checked the old facility, it soon concluded that it was not worth the conversion. The Planning Office argued that a better expenditure of state funds would be a remodeling of a section of the more substantial Laboratory.

Although legislative money was available as early as May 1978, telemetry was not moved to its present quarters until the summer of 1979, mostly because of many long discussions concerning the change of plan. The part of the Laboratory eventually occupied was the family apartment and the men's dormitory. Shortly thereafter both men's and women's dormitories were established in the original telemetry site following the installation of new exits and fireproof panels, and other modifications required by State policy and codes. The old building still houses a year-round machine shop, animal preparation room, bathroom facilities, and the Cedar Creek weather station.

Two additional buildings were built in the 1970's: in 1976, a 68 m² garage that houses a tractor and accommodates woodworking equipment used mostly in summer; and in 1979, a 223 m² storage building. Materials for both facilities were purchased from overhead generated at Cedar Creek, and station labor was employed when feasible. Other major expenditures of the 1970's were the installation of underground electrical lines and transformers to the Cedar Creek Laboratory, a Data General Nova 2 computer, and a deep well that feeds a copious supply of water to Professor McKinney's duck enclosures.

A major building program is anticipated for 1983-1984 in order to accommodate increased research activity. A proposed addition will adjoin the east end of the Laboratory and house much needed wet and dry laboratories, a special soils laboratory, weighing room, plant-insect-vertebrate collections, and several additional offices. A year-round housing unit is also planned. The building project is being funded by a $100,000 subvention from the biological Research Resources Program of NSF, with additional cost sharing funds of $35,000 from the University of Minnesota, and $25,000 from the Minnesota Freshwater Foundation. The target date for completion is February 1984.

Protection Of Cedar Creek

In view of an ever-expanding population flowing northward from the Twin Cities, a high priority must be given to protective policies and measures governing not only Cedar Creek's internal use but its many borders as well. The importance of this crystallized in the early 1970's when it became apparent that one of several proposed international airports abutted Cedar Creek; a rumor at the time was that the undeveloped land (Cedar Creek) would be an ideal dumping ground for unwanted fuel by circling aircraft in an emergency situation. That particular rumor was probably not well founded, but nevertheless it and similar suggestions prompted a search for more state and federal protection than was afforded Cedar Creek at the time.

The first move was to interest the National Park Service in Cedar Creek. For several years the Service visited and evaluated the area's habitats and management policies. Finally in December 1975 Cedar Creek was designated one of the Nation's important Natural Areas. The following spring a ceremony sponsored by the Park Service took place on Cedar Creek's laboratory grounds with University of Minnesota President C. Peter Magrath as key speaker. Today a bronze plaque commemorating the event greets visitors entering the station's laboratory and calls attention to the importance of the area. Some supporters of Cedar Creek were disappointed to learn that the Park Service designation does not generate federal dollars for the site; however, it must be noted that it does prevent the flow of federal dollars to airport and other projects deemed harmful to the Natural Area.

State protection also was sought via the Department of Natural Resources' (DNR'S) proposed Scientific and Natural Area program. Nothing has come of this to date—not only because of long delays in the State's program, but also because there is yet no good plan for placing certain areas under the DNR's protective umbrella while committing others to experimental manipulation. A new scare meanwhile embraces Cedar Creek: a proposed landfill immediately adjacent to Cedar Creek's west side threatens the natural area with...
dust and noise pollution, either one of which spells certain disaster for Dr. Frank McKinney's internationally recognized waterfowl behavior studies. The proposal is, fortunately, becoming less popular, mostly through the efforts of Dr. G. David Tilman and the recognition that Cedar Creek sits on an extremely important underground aquifer that feeds water to the Twin Cities. Activity of this sort once again forces us to seek additional state protection.

Equally serious problems relate to the country roads that dissect the natural area and place the public in close contact with such ecologically fragile areas as Beckman Lake. Recent road modifications have cut dangerously close to the lake's boggy margins of black spruce and other plants rare to southern Minnesota. Considering the area's wildlife, and especially its large deer population, speed limits should be lowered and enforced. Judging by the huge amount of litter strewn along Cedar Creek's roads, a certain disrespect for natural areas by some of our citizens cannot be ignored.

After great debate it was decided that some kind of fencing was necessary to protect some of Cedar Creek's outer flanks, even though the cost seemed prohibitive because of the many miles along the area's southeastern border erected during 1979 and 1980 to discourage trespassing and poaching. No fence was thought to be impenetrable, but it was decided that a low fence comparable to that used by the DNR would help. Deer confinement would not be a problem since they could easily clear such a fence. On the other hand, it seemed likely that snowmobilers, grazing horses, and unmanaged dogs on the hunt would be deterred.

Continuous cognizance of these many problems, and great expenditures of time and energy are necessary to offset habitat destruction of the future.

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Avian Use of Nest Boxes in Minnesota Farmstead Shelterbelts

RICHARD H. YAHNER*

ABSTRACT—A study of nest box use from November through August by birds in Minnesota farmstead shelterbelts was initiated subsequent to a two-year study showing that cavity-dependent species were absent from shelterbelts during winter and spring. The purpose of the study was to determine use of nest boxes by birds in shelterbelts otherwise devoid of cavities for roosting and nest building. Nineteen of 22 boxes (86%) were used as nest sites in spring and summer by house wrens (Troglodytes aedon) and black-capped chickadees (Parus atricapillus). Neither nesting in the shelterbelts before the nest boxes were available. Red-breasted nuthatches (Sitta canadensis) roosted in nest boxes during winter but had not been found in shelterbelts during the previous 2 years. A lack of snags or artificial cavities apparently limits densities and distributions of several cavity-dependent species in farmstead shelterbelts. Thus, provision of nest boxes and retention of snags in shelterbelts should be an important management consideration for landowners in intensively-farmed regions of the Midwest.

Abundance and distribution of cavity-nesting birds are contingent on the availability of food and nesting or roosting sites (Brewer, 1963; Mueller, 1973; Galli et al., 1976). Farmstead shelterbelts in the Midwest are man-made habitats consisting of rows of trees and shrubs that are designed to protect farmsteads from inclement weather in winter (Smith and Scholten, 1980). Shelterbelts also serve as important avian habitats throughout the year (Martin, 1980, Yahnner 1981, 1982a). However, snags are virtually absent from many farmstead shelterbelts (Yahnner, 1983) and cavity-dependent birds may be restricted in their use of these habitats. During a two-year study (1978-80) of avifauna in shelterbelts, wintering or breeding species that require cavities were absent (Yahnner, 1982b, 1983). The purpose of this study was to test the effects of nest boxes on use of farmstead shelterbelts by cavity-dependent species during winter and spring of the following year.

MATERIALS AND METHODS

The study was conducted from November 1980 to August 1981 at the Rosemount Agricultural Experiment Station, Dakota County, Minnesota. Four farmstead shelterbelts were selected for study, ranging in date of establishment from 1946 to 1961 and in size from 0.37 to 0.79 ha. Number of rows of trees and shrubs per shelterbelt ranged from four to nine, with widths of 14 to 27 m, and lengths of 162 to 498 m (see details in Yahnner, 1982a, 1982b).

Nest boxes were constructed of 2.5 cm pine and were painted with oak stain. Inside dimensions of boxes were 12.7 × 12.7 × 20.6 cm. An entrance hole, 2.9 cm in diameter, was positioned 15.2 cm above the base; 5 cm of wood chips and sawdust were placed in each box. This box design was intended to attract three “target” species, including black-capped chickadees (Parus atricapillus), red-breasted nuthatches (Sitta canadensis), and house wrens (Troglodytes aedon), but to exclude larger species (e.g., house sparrows, Passer domesticus). The 22 nest boxes were spaced 50 m apart along a medial row of trees in each of the four shelterbelts in early November 1980. Each was placed 2 m above the ground, and entrance holes were oriented southeast.

From November 1980 to late August 1981, boxes were inspected every 5 to 10 days for avian use (based on presence of feathers, feces, nesting material, eggs, or young).

Seven habitat variables measured in the vicinity of each nest box were: (1) basal area, (2) frequency of trees (>7 cm diameter breast height, DBH) within a 15 m radius of the box, (3) density (no./m²) of shoulder-high contacts of shrubs (woody plants < 7 cm DBH) in 2 perpendicular transects, each 1 m in width and 15 m in length, (4) maximum canopy height (m) in a 15 m radius of the box, (5) distance (m) to the nearest clearing, defined as an area > 3 m in radius and devoid of trees and canopy cover, (6) distance (m) to the nearest boundary of a shelterbelt, and (7) DBH (cm) of the tree to which a box was attached (modified from Conner and Adkisson, 1977).

RESULTS

Nest box use

In the two breeding seasons (1978-79) prior to erection of nest boxes, black-capped chickadees and house wrens did not nest in the shelterbelts at the Rosemount Station. From mid-May to mid-July 1980, one black-capped chickadee and 20 house wren clutches were produced in 15 (68%) percent of the 22 boxes. One of the 15 boxes was used successfully by both species at different times: a pair of black-capped chickadees occupied the box from mid-May to late June, and a pair of house wrens used the same box from mid-July to late August. No clutches of either species were found in the remaining seven boxes, but three of these contained partial nests of house wrens (see Bent, 1948). Abundant avian feces and a dead red-breasted nuthatch were found in two adjacent boxes in the shelterbelt during winter 1980-81. In addition, five (22.7%) percent of the boxes were used as nest sites by Parus minor m. canadensis in July and August 1981.

Production of young in nest boxes

One brood of house wrens was fledged in 13 (59 percent) of the 22 boxes, whereas two broods were fledged in two (9 percent) boxes. Eleven (55 percent) of the 20 clutches produced by house

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wrens were initiated in mid-to-late May, three (15 percent) in mid-to-late June, and six (30 percent) in mid-July (hereafter May, June, and July clutches, respectively). July clutches were produced only in boxes that previously contained May clutches, suggesting that perhaps the same pair renested in that box. June clutches were never followed by a subsequent clutch.

The single clutch produced by black-capped chickadees consisted of nine eggs, eight of which resulted in young that fledged in late June. A total of 114 eggs was produced in the 20 clutches of house wrens during the study: 70 (61 percent) occurred in May clutches, 19 (17 percent) in June clutches, and 25 (22 percent) in July clutches. Mean number of eggs per clutch was 6.4 (SD = 1.4) in May, 6.3 (±0.6) in June, and 4.2 (±1.7) in July for both successful and unsuccessful clutches (P = 5.0; d.f. = 2, 17; p < 0.05; simple-classification analysis of variance; Sokal and Rohlf, 1981). Second clutches (July, N = 6) of house wrens tended to have fewer eggs compared to first clutches (May or June, N = 14).

Ninety-two (81 percent) of the total eggs produced by house wrens resulted in fledged young. Fifty-eight (63 percent) of the 92 successful young came from May clutches, 14 (15 percent) from June clutches, and 20 (22 percent) from July clutches. Mean number of young house wrens fledged per clutch was 4.8 (SD = 2.7) in May, 4.7 (±0.6) in June, and 3.3 (±2.6) in July; these means were not significantly different (F = 0.7; d.f. = 2, 17; P > 0.05). Moreover, an average of 4.2 young house wrens was fledged in each of the 22 boxes during the year, giving a production of 35.9 young per ha (total area = 2.56 ha).

Relationship between habitat and breeding success

Three of seven habitat variables measured in the vicinity of nest boxes varied (P < 0.05; Wilcoxon two-sample test; Sokal and Rohlf, 1981) between successful boxes (boxes in which at least one brood of either house wrens or black-capped chickadees was fledged, N = 15) and unsuccessful boxes (box in which no broods were fledged, N = 7). Frequency of shoulder-high contacts of shrubs was less near successful boxes (mean ± SD = 0.57 ± 0.51 contacts/m²) than near unsuccessful boxes (1.31 ± 0.41 contacts/m²) (Mann-Whitney U = 85). Successful boxes were attached to trees of larger DBH (31.9 ± 16.8 cm) compared to unsuccessful boxes (19.9 ± 3.3 cm) (U = 81). Further, successful boxes were positioned at greater distances from nearest boundaries of shelterbelts (10.3 ± 2.8 m) than were unsuccessful boxes (7.1 ± 2.7 m) (U = 80).

DISCUSSION

A lack of cavities is apparently a major factor determining use of farmed shelterbelts by small, cavity-dependent avian species, although food availability, shelterbelt dimensions, and other factors also may be important. Family groups of black-capped chickadees were common in shelterbelts during summer and autumn prior to the present study (Yahner, 1983), suggesting that food resources were not limiting use of these habitats (see Mueller, 1973).

House wrens and black-capped chickadees occur in forest edges (Kendeigh, 1942; Johnson, 1947; Brewer, 1963), but breeding densities may be reduced by restricting nesting habitats to very narrow strips (Stauffer and Best, 1980). However, both species nested in boxes despite the narrow width (27 m) of shelterbelts in this study. House wrens readily occupy a large percentage of available nest boxes in other habitats. For example, Willmer et al. (1983) noted that 23 (45 percent) of 51 boxes were used for nesting by house wrens in a Maryland habitat characterized by abandoned farmland and woodland. Red-breasted nuthatches occurred in extensive woodlots within 1 km of the Rosemount Station in winters 1978-79 and 1979-80 (personal observation) but were never observed in shelterbelts (Yahner, 1983). After placement of nest boxes in the shelterbelts, a pair of red-breasted nuthatches was sighted regularly in one shelterbelt containing boxes (Yahner, 1982c).

The current study provides no evidence that house wrens prevented black-capped chickadees from using nest boxes or shelterbelts (see Bent, 1948; Scott et al., 1977). Perhaps, at least in black-capped chickadees, few birds nested in shelterbelts when boxes were available because young birds may select suitable nesting areas in late summer or early autumn; this searching period preceded the November placement of nest boxes (see Adams and Brewer, 1981).

Kendeigh (1942) recognized two nesting periods in house wrens, May-June and July-August, in Ohio. Further, he found that a greater percentage of total nests was constructed during the first period (N = 737, 70 percent) relative to the second period (N = 319, 30 percent) over a 19-year study. No nests of house wrens were initiated in August in the present study, but percentages of nests constructed per period in Kendeigh's (1942) study were identical to those obtained during the May-June period (N = 14, 70 percent) and the July period (N = 6, 30 percent) in this study. An average clutch size of six to seven eggs in house wren nests (presumably constructed in both natural and artificial cavities) in Pennsylvania and New Jersey (Harlow, 1918) was comparable to the average clutch size in May-June nests but not in my July nests.

Long-term nesting studies of house wren productivity have been based on nest box use in a variety of habitats. For instance, Mcabee (1940) found that 84 percent of the total eggs (N = 469) resulted in fledged young in Maryland orchards. Kendeigh (1942) observed that 79 percent of the total eggs (N = 6773) resulted in fledged young in Ohio deciduous forest edges. Thus, an 81 percent success rate of total eggs in my shelterbelts is similar to productivity of house wrens in other types of habitats. In contrast, Walkinshaw (1941) noted that only 48 percent of the total eggs (N = 333) produced resulted in fledged young in Michigan bottomland forests.

Snags are often removed from shelterbelts by landowners (Yahner, 1983). Therefore, provision of nest boxes in shelterbelts conceivably could minimize intra- and interspecific competition for cavities (Enskine and McLaren, 1976; McBroom and Noble, 1978), thereby affecting distribution and abundance of these small cavity-dependent species in the intensively-farmed regions of the Midwest where cavities are scarce (Gallei et al., 1976). Further, the value of this management practice to birds, such as house wrens, may be enhanced if nest boxes were placed in areas relatively devoid of dense woody stems, are positioned away from the periphery of shelterbelts, and are attached to large diameter trees. Based on my data, nests constructed in boxes at these locations were less susceptible to failure. Perhaps nest boxes located in areas of shelterbelts with reduced woody stem density allow house wrens to better detect and deter potential nest predators (e.g., suakie, Pheucticus; see Kendeigh, 1942). Because predator use of linear habitats is highest at edges (Gates and Gysel, 1978), possibly nests in boxes positioned within the interior of shelterbelts were less likely to be encountered by a potential predator than boxes in trees near boundaries of shelterbelts. Greater nesting success in house wrens that used boxes attached to large diameter trees may be related to box dimensions. Total width of nest boxes in my study was about 25.6 cm. Conceivably, boxes of this dimension were less
conspicuous to predators when against backgrounds of larger diameter trees (X = 31.9 cm for successful nests) compared to boxes attached to smaller diameter trees (X = 19.9 cm for unsuccessful nests). Finally, an additional management recommendation may be to vary heights of nest boxes in shelterbelts. For instance, heights of natural cavities used by nesting black-capped chickadees and house wrens averaged 2.2 and 5.4 m above ground, respectively, in Iowa riparian habitats (Stauffer and Best, 1982).

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The Minnesota Academy of Science
Issues in Teaching Science

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ABSTRACT — Vital issues in the science curriculum include: 1) product versus process goals; 2) inductive versus deductive learning; 3) a psychological versus a logical curriculum; and 4) subject centered versus activity centered units of study. Each student needs to achieve optimally regardless of the position(s) taken by science teachers on any one of the above named issues.

There are diverse issues in the teaching of science. The purpose of this paper is 1) to make comparisons between two equally recommendable methods of teaching 2) to reveal the writer's beliefs that issues need resolving and 3) to recognize divergent philosophies in developing an effective science curriculum.

Product versus Process Goals. Creating worthwhile products can be a desirable goal in education. In this view, achieving an end or objective on the pupil's part is paramount. If products are to be salient in ongoing lessons and units, adequate effort must then be given in the selection of relevant objectives for students to attain. Also, the teacher needs to choose learning activities (means) to attain the objectives and to evaluate if the involved pupil successfully achieved the objective. Evaluation is based solely/largely on pupils' achieving the objectives.

Which end products, then, might learners achieve?
1. acquiring vital facts, concepts, and generalizations.
2. making science equipment directly relating to an ongoing unit.
3. completing art projects, such as murals, dioramas, friezes, and sketches pertaining to relevant science concepts and generalizations.
4. writing poems, stories, and plays, individually or in committees.
5. making models and objects involving science phenomena.

Somewhat toward the other end of the continuum, some teachers and supervisors advocate process rather than product objectives. Which process goals might be valuable for learners?
1. working together cooperatively in a committee endeavor
2. identifying and solving problems in ongoing science units.
3. observing, classifying, and interring science phenomena, responsibly and accurately.
4. taking notes, outlining, and summarizing.
5. reporting subject matter orally and effectively utilizing quality standards.
6. dramatizing relevant events from the lives of famous scientists.
7. reading science content involving proficient comprehension.
8. utilizing a variety of purposes in listening to facts, concepts, and generalizations in the science curriculum.
9. using methods of science to acquire and appraise data.
10. becoming skillful in the use of science equipment within a laboratory setting.

Inductive versus Deductive Learning. Inductive methods can be utilized effectively in teaching science (3). To emphasize induction, the teacher needs to utilize a variety of activities in stimulating pupils to respond effectively to questions raised in ongoing units and lessons. The science teacher does a minimum of lecturing and explaining of subject matter to pupils. Rather than lecturing and explaining content, the teacher guides pupils to make discoveries and find out on their own. Skilled teachers raise relevant questions so that learners may be guided to achieve viable generalizations. Inductive teaching emphasizes moving from specifics to the general to attain significant broad ideas.

Other science teachers stress deductive means of teaching pupils. Well planned lectures and explanations may then provide major learnings for pupils. Also, learners can obtain subject matter deductively from films, filmstrips and cassettes, single or multiple series science textbooks, tapes, illustrations, and demonstrations performed by the teacher. With deductive means of instruction, subject matter is presented by the science teacher for learners to acquire.

No science teacher, perhaps, uses either a pure inductive or pure deductive method. However, a teacher may lean heavily in the direction of using either method of teaching and learning. In each situation, learnings for pupils need to be meaningful, purposeful, as well as provide for individual differences. Learners individually need to achieve optimally in the science curriculum.

Psychological versus Logical Curriculum. A psychological curriculum emphasizes pupils' being rather heavily involved in sequencing their own learnings. For example, in an individualized reading program in science, each pupil generally selects which library books to read first, second, third, fourth, and so on. After each book has been completed in reading, pupils with teacher guidance may appraise progress of the former. Means of appraisal may also be determined by pupils with teacher assistance.

As a further example of a psychologically designed curriculum, a science teacher may develop a set of learning centers. There needs to be an adequate number of centers so each pupil might sequentially select tasks to complete, as well as to omit. The teacher is a guide and stimulator to encourage pupils to progress sequentially and optimally.

A logical science curriculum is developed with the teacher selecting ordered goals in ascending levels of complexity for learners to attain (4). The teacher also chooses learning activities to guide each pupil to attain measurable ends. The teacher must evaluate if a learner has been successful in goal.
attainment. Each pupil that successfully achieves an objective may tackle the next sequential goal. If a pupil does not attain an objective, the teacher might then need to utilize a modified teaching strategy.

The teacher determines sequence for pupils, individually, in arranging objectives, from simple to increasingly more complex. A logical science curriculum is being emphasized in these teaching-learning situations.

Subject Centered versus Activity Centered Curriculum. Acquisition of vital subject matter can be a salient goal to emphasize in ongoing units and lessons. Understanding objectives then receives considerably more emphasis compared to skills and attitudinal goals. In learning much subject matter, pupils are guided to comprehending well from the utilization of single or multiple series science textbooks, related workbooks and worksheets, general encyclopedias, content centered audio-visual aids, and science encyclopedias, among other reference sources. Pupil achievement from the above-named activities may be evaluated through teacher directed discussions and observation, as well as by use of true-false, multiple choice, essay, matching, and completion items.

A project method presents a different school of thought. Subject matter then is learned only to develop and complete relevant projects. In project methods of instruction, pupils are active, not passive, beings. The learner-with teacher guidance-plans, develops, and evaluates each project. The projects might include making science equipment and models, as well as being involved in art and dramatization activities.

In conclusion, there are diverse issues to be resolved in the science curriculum. How much emphasis then should be placed upon:

1. product as compared to process goals?
2. induction and deduction as methods of teaching?
3. a psychological as well as a logically developed curriculum?
4. the learning of subject matter as compared to actively participating in selecting and developing diverse projects in ongoing units of study?

Whichever method or approach is being emphasized in teaching and learning, learners need to develop interest, purpose, and meaning.

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MINNESOTA'S GEOLOGY
Richard W. Ojakangas and
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University of Minnesota Press, 1982.
255 pp.
reviewed by Henry Lepp, Department of Geology,
Macalester College

Although the authors of Minnesota's Geology claim their book is a "companion volume" to Minnesota's Rocks and Waters, knowledgeable readers will recognize it rather as the successor to the earlier work. More than simply a revision of Rocks and Waters, however, the book stands as a complete new work on the geology of Minnesota that like its predecessor is well written and likely to appeal to all interested persons regardless of geologic training.

The science of geology has undergone dramatic changes during the decades since Minnesota's Rocks and Waters was written—for those who use the term, we might say that the field experienced a scientific revolution in the 1960's. When Rocks and Waters was written radioactive dating was in its infancy. Most American geologists of the time adhered to the idea of the permanence of continents and ocean basins; moving continents were considered a fantasy and the concept of shifting plates was unheard of.

In the wake of the dramatic advances in many areas of earth science it became increasingly clear that Minnesota's geological story needed to be retold in the context of these new discoveries. In Minnesota's Geology, this need has been met admirably, and the publisher has produced a most attractive and well illustrated work.

Because the book is intended for all interested persons, it begins with a briefing on the basics of geology. In order to understand the geology of the state the reader must first know something about rock and mineral nomenclature, the geologic time scale, earth structures, fossils, and other basics, as well as the relation of Minnesota to the rest of North America and the world. Part I of the book nicely covers this background material.

Part II (chapters 3-7) deals with the geologic history of Minnesota from the Early Precambrian (2500-4500 million years ago) to the Quaternary (2 million years ago to present). Such a review of geologic history with its dates, rock units, periods of orogeny, etc. could well be boring; by placing the facts in a broader context, however, the authors make a potentially dry subject refreshingly readable. They not only tell what is known about the geologic history but also devote considerable time to how we know and thus introduce many geologic concepts not covered in Part 1. Moreover, they continually tie the Minnesota story to the larger story of the evolution of North America and planet Earth.

Part III is a summary of the actual and potential mineral and fuel resources of the state. Minnesota is primarily known for its iron ores; these are thoroughly described with the aid of fine maps, cross-sections and photographs. Deposits of nickel, gold, uranium, silver, various non-metals, peat, oil and other resources are covered as well. And, there are numerous enlightening historical sketches, including one on the oil ventures in Minnesota during the late 1800's.

Part IV, which deals with Regional Geology, will be much appreciated by those whose appetites have been whetted by earlier sections. The authors divide Minnesota into five regions and provide a description of the topography, glacial geology, bedrock geology, and a list of places of interest for each. By going to the 'places of interest' and by following the detailed road logs included with some, the reader can gain a first-hand appreciation of the Minnesota's rocks and history.

No book is perfect, however, and Minnesota's Geology admittedly has a few glitches. Minerals are twice described as compounds, leaving diamond, graphite, gold, silver and others in limbo. The statement that oxygen and silicon make up over 90 percent of the crust by volume will mean nothing to those not familiar with ionic radii; the real point of interest here is the fact that oxygen alone makes up over 90 percent of the crust by volume whereas silicon, the second most abundant element on an atomic or weight basis, makes up a scant 0.2 percent by volume.

Although the authors admit that the origin of iron formations is still a subject of debate, their tale of how oxygen might suddenly have precipitated hematite and magnetite is misleading (at least in Minnesota's cases) since on the giant Mesabi range ferrous minerals like siderite and iron silicates, which would not form in the presence of oxygen, are together at least as abundant as the oxides. The statement that the iron formations and iron ores are of three distinct ages (page 127) is dramatic but not true, even according to the authors themselves. They suggest that vulcanism may have played a role in the development of the Middle Precambrian iron formations; however, this is also their model of origin for the Early Precambrian formations. The same applies to the secondary ores; the Fillmore county ores actually were formed in the same way as the Mesabi ores—by residual concentration during weathering.

A number of other minor faults leave the book less polished than it might have been; several figures, for example, may confuse the newcomer because each portrays three geologic systems under a single color code.

In spite of a few rough spots, however, this is a well-written book that should serve the amateur and even the professional for as long as its predecessor. When used by a teacher with some appreciation of the subject, the book will make a fine text for a course on the geology of Minnesota.
In agreeing to review *Springs of Scientific Creativity* I naively thought that I would learn something about creativity and so gain a competitive advantage over other working scientists. Unfortunately, I was disappointed. I learned little about how to be creative and I'm even a little less certain than I was before as to what the term means. What emerges for the most part can be summarized in the words of two contributors: "Creative thinking is a mystery and probably will always be so," and "The search for a method of creativity is destined to fail." The approach used to explore creativity is mindful of the story of the blind men placed around the periphery of an elephant and then are asked to describe the elephant from touch: the lives of a number of historically famous scientists are explored by various writers, who then attempt to identify the nature and origin of creativity in each.

The biographical sketches and vignettes cover the lives of Galileo, Newton, Joules, Maxwell, Gibbs, Rayleigh, Sperry, Nernst, Einstein, Schrodinger, Polanyi, and von Neumann, leading the reader to suspect that the editors took to heart the patronizing comment of Lord Kelvin, who is reputed to have said that science can be divided into two parts—physics and stamp collecting. Each sketch is written by a different authority, but we are heavily laced with details of the subjects' work. Most provide a quite readable description of the character and roots of each subject as well as the society within which they lived.

Although this approach carries with it an inherent discontinuity, it is preferable to others that have been applied (e.g., the study of Einstein's brain in the hopes that an anatomical explanation could be found for his genius, and attempts to develop inventory scores to be used to evaluate and predict individual creativity.) This book is a far more honest attempt to evaluate creativity and creative thinking.

By far the most interesting and longest essay is about James Maxwell, whose electromagnetic theory of light helped to make him one of the giants of modern theoretical physics. Other essays, unfortunately, make more sparing use of biographical material. The writing, while generally good, is uneven, and some sections give the reader the sense that he is reading a speech, not an essay. As a consequence, the organization of the essays is sometimes confusing. The chapter on Galileo—the first in the book—is poorly organized. In defense of this contributor (Thomas Settle), there was much less biographical material available than in the case of later subjects.

If, then, as *Springs of Scientific Creativity* elucidates, we cannot be sure of what creativity is, what conclusions can be derived from the examination of these lives? First, it is true that many of the creative geniuses had special abilities not given to us all. For example, the idea that geometry and Latin were good "training for the minds" was apparently unnecessary for Einstein, who was able to prove the Pythagorean theorem before the age of twelve without the benefit of first studying geometry. Were then special inherited abilities the key to their eventual success? To an extent, perhaps, but no more so than their splendid educations. One feels however, that as important to their success was their environment, including their associations.

One wonders if Einstein, Joule, or the others would have achieved the creative success in today's world. Could they—or would they—have written the requisite grant proposal which must state clearly, succinctly, and most of all logically the purpose of the proposal? The chances are that they would not. Then too, they may have rebelled against the need to outline the future of the project. After all they were not in the business of "future predictions." No, these people—are our forebears—are those who in the words of contributor Thomas Hughes must be in an "environment in which restless souls... would be exposed to never ending change encouraged in their belief that from chaos an order of their own design might be imposed... ." This is the powerful message which this book conveys. In a world where the notion of science administrators is "that an environment can be designed to eliminate risks, the failures, the unpredictableness and the elusiveness of creativity," we may be making a great mistake. Institutional Science which can balance the financial books may encourage efforts to learn about creativity, but at the same time also stifle creativity itself.

This book is also beneficial in that it gives a human aspect to science. The lay public and many professionals often view science as a body of facts and principles to be tested and restated by a large, amorphous, anonymous horde. Publication of books such as that by Broad and Wade (Betrayals of the Truth: Fraud and Deceits in the Halls of Science; Simon and Schuster, 1982), which details the behavior of certain contemporary "investigators" caught in their conniving ways for the advancement of their own careers, also wreaks our sensitivities. *Springs of Scientific Creativity* is a refreshing antithesis. Great scientists are portrayed not as paragons of virtue, single-minded in their efforts to advance science, but as real people, foibles and all, with extraordinary gifts.

This is a highly readable book once past the details of individual accomplishments with which most readers will be unfamiliar. Much new food for thought will trickle out of the *Springs of Scientific Creativity*. 

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**Springs of Scientific Creativity: Essays on the Founders of Modern Science.**

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