A Brief History of the Cedar Creek Natural History Area

A. C. Hodson

According to William S. Cooper he first saw Cedar Creek bog while on an airplane trip on April 6, 1930, and later that year he and Dr. Rosendahl investigated the place on foot. There had been one previous visit to the Isanti portion of what was originally called the Cedar Creek Forest by N.C. Huff in 1929. Helen Buell, the wife of Dr. Murray Buell, had called attention to the fact that the Cedar Bog Lake was referred to as Decodon Bog because Drs. Rosendahl and Butters were so impressed with the amount of Decodon growing there.
As will become very evident, the Minnesota Academy of Science became much involved in the early development of the Cedar Creek Forest. The Academy held its first annual meeting in 1933 with William A. Riley serving as its first President. In 1937 the Minnesota Academy of Science was incorporated. That same year the Academy established a Committee on the Preservation of Natural Conditions. Dr. Cooper, who was President of the Academy at that time, asked Dr. Arthur N. Wilcox to serve as Chairman of the Committee and suggested that there should be six members, evenly divided between plant and animal fields. Soon after the Committee was appointed, its attention was called to the desirability for acquiring and preserving a portion of the area known as Cedar Creek Bog. Within the next few years, the Academy, with the aid of Drs. Cooper, Buchta, and Gould, was able to obtain the donation of sufficient funds from about 25 members so that by 1940 arrangements were made to purchase important parts of the area.

At this point one should pay tribute to Cora Alta Cornelia who made truly outstanding and unselfish contributions to the project. From the 1930s through the 1940s and for most of the 1950s, she was either buying land herself, paying taxes on it, or holding it until a permanent organization could be formed to preserve the area in the public interest. She also took steps to interest scientists, professors, deans of the University and others to move in the direction of public or semi-public ownership. According to Grace Nute, if only one person could be held responsible for beginning the crusade to save Cedar Bog, that individual would be Cora Cornelia.

The purpose for which land in the Area was desired seemed to justify and require a tax-free status, so it was concluded that the University of Minnesota would be the most suitable public agency to preserve the Area and administer it wisely for its intended uses. To further action on this conclusion, Dr. Wilcox and Dr. O.T. Walter, President of the Minnesota Academy of Science, wrote to University President Gary Stanton Ford saying that they would like to discuss with him the desirability of University ownership on a tract of land to be preserved for scientific and educational purposes. Two years later, in 1942 an agreement between the Academy and the University was executed, providing for the conveyance of lands and the establishment and administration of the Cedar Creek Forest as it was designated at that time.

Soon after this, a number of individuals including Dr. Donald Lawrence and his wife donated parcels of land, as did the Minnesota Natural History Society under the direction of Dr. Clayton Rudd. Thus, an ambitious land acquisition program got underway. And it now became time to make arrangements for the administration of the Area. Dr. Wilcox suggested to Dr. Walter C. Coffey, the University President, that there should be an Advisory Committee appointed that would be directly responsible to the Dean of the Graduate School, including representation from the Minnesota Academy of Science. Thus, in May of 1945, an Advisory Committee consisting of Dr. Wilcox as chairman, Professor Ernst Abbe (Botany), Professor Dwight Minnich (Zoology), and the Dean of the Graduate School, Theodore R. Blegen, an ex-officio, was appointed. The University President, J. Morrill, invited the Academy to select an Advisory Committee of three to advise the University Committee in the administration of the forest and its uses. Those selected were Professors O.T. Walter of Macalester College; Harvey Stork, Carleton College; and the Rev. Adelard Thuente of St. John's University. One of the first acts of the joint Committee was to request a grant from the Graduate School for an aerial survey and mapping of the Forest which was carried out under the direction of Dr. Lawrence. A more urgent matter was undertaken when the Committee drew up a set of regulations for the use of the Area. They included the provision that research projects involving collecting, experimentation, or other disturbance of natural conditions could be carried out only after application to and approval of the Advisory Committee.
Among the first to carry on comprehensive research on Cedar Bog Lake were Dr. Murray Buell and his wife, Helen. They established a transect in 1934 in order to make an elevation survey and marked trees with railroad spikes three of which are still visible. Dr. Lindeman and others used the transect for other purposes. It was at Cedar Creek Bog that Ray Lindeman did his monumental research. He published six papers the last of which is still referred to as the “Classical Paper of Lindeman,” and has been described as the “most significant formulation in the development of modern ecology.” The article, entitled “The Trophic-Dynamic Concept in Ecology” was published in Ecology in 1942. It had first been rejected by two prominent reviewers because it made too many assumptions.

In 1952 Dean Blegen mentioned to Dr. Wilcox that he had in hand considerable correspondence between Stanley Wenberg, then Director of the Greater University Fund, and Col. Schutte, who was not only a loyal alumnus of the University, but also a close friend of Wenberg and Mr. and Mrs. Max Fleischmann. The University took full advantage of these circumstances when it applied to the Max C. Fleischmann Foundation of Nevada for a grant. In June of 1854, Mr. Luden, the University Controller, received a message from Mrs. Fleischmann in which she said that the Foundation had voted in favor of a $250,000 grant. Of this sum, $165,000 was to be used for land acquisition, $75,000 for a headquarters laboratory building, and $10,000 for current operating expenses. During the next several months, there was a great amount of correspondence and many Advisory Committee meetings before a site for the laboratory...
could be selected and purchased and construction could get underway. In the same year, 1954, President Morrill appointed a new Advisory Committee with Dr. Wilcox as the first Director of Cedar Creek Forest and Dr. Minnich as Chairman of the Committee.

In 1956, an important event took place when Alvar Peterson was appointed as caretaker of the new laboratory. The following year, 1957, it was decided to combine the dedication of the new laboratory with the annual summer meeting of the Minnesota Academy of Science. The dedication took place in September with a noon luncheon and dedication address by Dr. Stanley Cain, the subject, “The Need for Natural Areas.” Also in 1957, an important decision was made when Dr. Lawrence’s application to use Cedar Creek for a project called “Some Energy Relations of Terrestrial Ecosystems” was approved. It was approved as the first experimental study which involved the harvesting of trees and other plants. This research was funded by a grant from the Hill Family Foundation.

In 1958, the National Science Foundation provided funds for stereographic aerial photography and contour mapping, and for the purchase and installation of equipment for the measuring and recording of weather data. In March, Dr. Dwayne Warner outlined his proposed research on the application of electronic methods to wild animal field studies. He applied to N.S.F. for a grant to support his proposed radio-telemetry project but was turned down because it was “too wild.” However, Mr. H.H. Heckman, Director of the Hill Foundation, was much impressed with the idea and the Foundation awarded the University a $40,000 grant to begin the project. From this beginning, the project expanded to become the largest telemetry program in the world which has influenced biological studies worldwide. This same year the name of the Area was changed from Cedar Creek Forest to Cedar Creek Natural History Area.

In 1962, the appointment of Dr. William Marshall to replace Dr. Wilcox as Director of Cedar Creek Natural History Area was announced. In October, the long and dedicated service of Dr. Wilcox as Director was recognized by a dinner attended by about 200 people. On the occasion, Dr. Wilcox was presented with a plaque which was mounted in the laboratory. It was fortunate that this event took place when it did because he died the following February.

By 1964, the activities at Cedar Creek had expanded greatly. Fifty research permits were issued and 800 persons visited the Area including students from the University and six local colleges. There were 175 visits by individuals who came from 19 United States and Canadian Universities and five foreign countries. There were also representatives from the Atomic Energy Commission, the Ford Foundation, U.S. Bureau of Sports Fisheries and Wildlife, and the U.S. National Museum. This same year the duck flight pens were constructed where waterfowl behavior studies have been carried out by Dr. McKinney and his students. At this time, Dr. Frank Irving started a prescribed burning program to maintain savannah-type vegetation. Other lines of research will be described by others contributing to this issue of the Naturalist.

In concluding this brief history, I would like to comment on a few more important events. In 1970, Dr. Marshall was replaced by Dr. David Parmelee as Director of the Field Biology Program to direct activities both at Itasca and at Cedar Creek. In 1975, the Cedar Creek Natural History Area was designated a Registered Natural Landmark by the National Park Service, and 1978 as a Scientific and Natural Area by the State. In 1981, Drs. Tillman and Tester were awarded $1.3 million to conduct a “long-term Ecological Research” project, one of 11 such projects in the United States. In January of 1983, a reception was held in the laboratory where Alvar Peterson was honored for completing 26 years of dedicated service to Cedar Creek. In 1984, the Field Biology Program was terminated and Dr. John Tester was appointed Director of the Cedar Creek Natural History Area.

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Parental Care in Raccoons and Snowshoe Hares—Revelations of Telemetry

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Many articles have been written about parental care and the relations between human parents and their offspring. On the other hand, relatively little is known about the behavior and maternal relations of many species of wild mammals. This is particularly true for those species that are secretive, live in forests, or other types of dense cover, or are active primarily at night. Knowledge of how young animals first develop independence from their mother is of considerable importance to understanding the biology of a species. Unfortunately, prior to the development of telemetry or radio-tracking techniques, this information was very difficult to obtain. Now, with the aid of radio-telemetry, we can obtain the minute-to-minute data essential for evaluating brief movements over short distances. The critical first movements of young raccoons and snowshoe hares have been especially difficult to observe directly because these mammals live in forests and are nocturnal. By using an automatic radio-tracking system at the Cedar Creek Natural History Area, we have learned that the relations between mothers and young in these two species are extremely different.

The data which provided the basis of this report were collected by scientists working on the radio-tracking project at Cedar Creek. Dean Schneider and L. David Mech were primarily involved in the raccoon studies and Orrin J. Rongstad in the snowshoe hare studies.

The Study

Hares were captured with live traps, with drive nets, and by hand. Each hare was tagged with a collar-type radio transmitter which broadcast on a unique frequency. The smallest transmitters, which weighed about 7.5 grams and had a battery life of 10 days, were used on four young hares between 5 and 21 days of age (Photo of young hare with radio collar). Transmitters for adults weighed approximately 37 grams and had an expected life of about six months. To ensure against loss of data due to battery failure, we recaptured the animals prior to the time that the battery was predicted to expire. Maximum range was about 0.5 miles for the small transmitters and just over one mile for the largest.

Five female raccoons and 11 of their young were captured with live traps, by extracting them from hollow trees, by capturing by hand, or with a net while the animal was running on the ground, and, in one case, by shaking the raccoon out of a squirrel’s nest. Each animal was collared with a radio transmitter which weighed between 75 and 125 grams.

The automatic tracking system had two permanent towers located 0.5 miles apart. Animal locations, called fixes, were determined by triangulation. Though it was possible to obtain locations every 45 seconds, we found that a fix every 15 minutes usually provided satisfactory information on movements of both mothers and young. During the day, when little movement occurred, we recorded fixes at one-hour intervals unless the film record of the signal indicated extensive movements. To investigate relationships between parents and offspring, every available fix was used during the time the animals were near each other.

Snowshoe Hares

Initially we had hoped that by plotting on a map the daily movements of female hares, we would see a pattern develop that would tell us when and where they had their young. We then intended to locate and radio tag the young so that their...
movements could be recorded. Though we could predict the approximate date of birth of a litter, we have never been able to locate the young. To solve this problem, we captured a pregnant female (identified as hare 225) and put her in a small temporary pen near her normal home range. She had a litter of four young on the night of July 12. The next morning, all four young were huddled together under a small shelter in the pen. They remained close to each other most of the time during the first few days of their lives. On July 18, we placed transmitters on the female and her four young. As all the transmitters were operating properly the next afternoon, we quietly raised the sides of the pen and allowed the hares to leave. On the day after release from the pen (day 8), all young were located with a portable radio receiver. Each was in a different hiding place, separated from the others by as much as 60 feet. Surviving young were captured periodically to replace the battery on the transmitters.

Although 225 had been trapped, moved to a strange area, and held in captivity while giving birth, she did not abandon her young. We lost radio contact with one young when it was 12 days old. A weasel killed another when it was 25 days old. The remaining two lived until the following March when one was killed by a red fox and the other moved out of range of the receiving towers and could not be relocated.

Based on locations obtained with the tracking system, the home ranges of 225’s young were between 1.6 and 2.4 acres during the second week of life. Each week until the hares were approximately 55 days old, their home ranges increased until they were about equal to adult home ranges. We assume that at the time of weaning, about 28 days, the young hares became independent of each other because their home ranges showed only a small amount of overlap.

Fixes obtained by telemetry were used to determine when hare 225 was with her young and how far away she went when she left them. The young did not remain together, but did stay in the general vicinity of the pen. The most striking discovery was that the female was with her young only once each day for only 5-10 minutes, and that the time when this occurred was remarkably constant from day to day. The female would often spend the rest of the day as far as 900 feet from the young. It is probable that the mother left her young as soon as they finished nursing and did not see them again until the next night.

After noting how little time 225 spent with her young, we re-examined the movement records of other females that had been monitored on a minute-by-minute basis. We found that there was one place to which an individual female returned each night, and that this place was probably where her young were hiding. An example of this movement pattern, plotted as the distance between the suspected birth place and that of female 220, is shown in Figure 1. We had originally failed to detect the place where the young of 220 were born and nursed because we had sampled her location only every 15 minutes. This sampling interval often missed the time that the family was together.

Female 220 first went to this special location at 1:20 a.m. on May 27 and stayed until 1:35 a.m. She probably gave birth

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*Figure 1 — Distance between female hare 220 and her young for various 24-hour periods during the time the young were nursing. Young were born on May 27, designated Night 1. Night 28 was apparently the time of weaning.*
to her young at this time. She returned to her young only once each night, with the possible exceptions of the first, second, and fifth nights. In Figure 1, these returns are shown as the time where the line on the graph indicating distance between mother and young reached the zero point on the vertical axis. The return occurred between 9:50 p.m. and 10:30 p.m. until night 27 (June 22), when she came to the general area at 11:00 p.m. and stayed 30 minutes. We had caught her with a drive net at 12:30 p.m. that same day to check for pregnancy; this handling may have affected her movements that night. The next night she did not approach within 300 feet of the nursing area, nor did she ever venture closer than this for the next 30 days. We expect that her failure to return on the 28th night was part of the normal weaning process. Female 220 had her next litter on the night of July 2 or 3.

It is apparent from the above discussion that mother snowshoe hares spend relatively little time with their young and that the young are able to function on their own at a very early age. In marked contrast, mother raccoons spend a great deal of time with their young, and the young do not leave the den until they are many weeks old.

Raccoons
Young raccoons are born in hollow trees in early May at Cedar Creek, and are kept in this den for many days. The mother generally uses the den tree for two or three days before giving birth. For a few days after birth, the mother's movements are greatly reduced, usually with no movement from the tree on the day of birth. In a short time, the mother resumes normal movements usually being gone eight to twelve hours or even longer during the night. She spends days in the den tree, probably in the nest cavity with the young.

Usually the mother moves her young to a ground bed when they are from seven to nine weeks old. No member of the family is likely to use the den tree again for the remainder of the year.

For several weeks, the cubs remain in a ground bed; however, they may be moved to new ground beds several times. When the cubs are nine to ten weeks old, they begin to follow the adult when she leaves the bed in the evening. She travels more rapidly than the cubs and soon outdistances them. They then make their way back to the bed and remain there.

In another few days, the mother spends part of the night escorting the cubs on short trips from the nest. These trips become longer and longer each night and soon the family is moving and bedding together at all times. Figure 2 illustrates this period for female 635 and her three cubs. Food is abundant now at mid-summer, because tadpoles are metamorphosing, grasshoppers are hatching, and berries are ripening.

Weaning occurs when the cubs are about 16 weeks old. Cubs occasionally travel without their mother at this age. In a few weeks, they begin to bed occasionally by themselves. From September into November, the cubs remain within the mother's home range, and may move and bed with siblings, with the mother, or alone. Cubs may not see their mother for several days, but on any given night, several temporary associations may form and dissolve among family members.

Figure 2 — Diary of the period when raccoon 635's cubs began to accompany her. Read the daily bars from bottom to top.

In late October or early November, the mother may begin to use hollow trees for bedding, and one of these will ultimately be selected as the winter den. Cubs may use these trees if they happen to be bedding with their mother, but they seldom sleep in them when not with her. During November, family ties are strengthened, as shown by an increasing tendency for the cubs and mother to bed together. Movement periods also become shorter and the winter den tree may be the only bed used. The first heavy snow storm of the season usually occurs at Cedar Creek in late November or early December, and at this point, movements cease with the family denned in the same tree or with members denned separately in nearby trees.

The strengthening of the family bond as winter approaches is especially interesting. It may be that the cubs need adult guidance to survive their first winter under the severe conditions found in Minnesota.

Conclusion
The marked difference in the behavior patterns of mother and young in snowshoe hares and raccoons present a striking contrast in the way that different species of mammals, about the same size and living in the same area, are adapted to survive. Obviously, one system is not necessarily better than the other; each is a successful adaptation to the Cedar Creek environment.

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Visitors to the Cedar Creek Natural History Area (CCNHA) are seldom impressed by its landscape. The Area consists of a mosaic of subdued hills or small rises intermingled with wetlands. In addition, examination of roadbanks and trails through the area soon reveals that sand, remarkably uniform in grain size, is all-pervasive. To the casual observer, then, the geologic environment of CCNHA is rather uninteresting compared to the diversity of its flora and fauna. This, however, is not the case. Both the geologic events that gave rise to the landscape of CCNHA and the pattern of present-day soils are intriguing. I hope that an explanation of those events and patterns will illustrate that the area is even richer than when only the flora and fauna are considered.

The story begins, as do all good stories, a long time ago. Because the record is faded, we don't really know exactly when it all began. There is no question that glaciers and their geologic aftermath have shaped the present landscape of Minnesota, including CCNHA. Some of the best guesses place the arrival of the earliest glaciers in Minnesota at over one million years ago. Subsequent glaciers have erased most of the evidence of those earlier glaciers, however, and the best information is available for glaciers that crossed the state during the most recent, or Wisconsin glaciation.

During the Wisconsin period, glaciers moved across the state from the north, the northeast, and the northwest. The area of CCNHA was covered by glaciers from both the
northeast and the northwest. A lobe of glacial ice flowed out of the present basin of Lake Superior and headed south from what is now the Duluth-Superior area toward the Twin Cities. That Superior Lobe, as did all continental glaciers, carried till or unsorted debris with it much as does a conveyor belt. The southernmost front of the ice maintained a position at about the area of the Twin Cities for a long time, with the rate of ice flowing from the north balanced by the rate of melting in the south. Debris moving with the ice continued to accumulate, forming the hills that now dominate the landscape of the Twin Cities in such areas as Fridley, Apple Valley, and Prior Lake. Eventually, probably because of climatic change, the source of supply of the ice ceased and the entire lobe melted. Melting was slow, and large chunks of ice, protected by thick layers of debris, persisted for hundreds of years. In the area of CCNHA, some of this buried ice filled valleys in which water from the melting ice had previously flowed; these valleys trended northeast to southwest.

Before this buried ice had completely melted, the area of CCNHA was covered by another glacial lobe. This lobe entered the state from northern North Dakota, and eventually split into three sublobes, one of which extended as far south as Des Moines, Iowa, a second that extended into St. Louis County, Minnesota, and a third that reached Grantsburg, Wisconsin. Ice from the Grantsburg Sublobe covered CCNHA (Fig. 1). The source of supply of ice to the Grantsburg Sublobe ceased about 14,000 years ago, and the ice began to melt. Melting of a glacier is not an orderly process. Melting can occur from all directions of the compass, and from the top down and from the bottom up. As the ice melts, the debris that is present in the ice is released. Large volumes of water from the melting ice flow through the debris, carrying off some debris and leaving the remainder behind.

Cooper, in 1935, published a report in which he described his conceptualization of the melting of the Grantsburg Sublobe and the formation of the Anoka Sand Plain, the landform of which CCNHA is a part. Cushing, in 1963, elaborated upon that explanation, and that collective hypothesis follows. Some of the meltwater from the Grantsburg Sublobe flowed north, where it was joined by meltwater from other parts of the Des Moines Lobe. The water was prevented from leaving the area because the higher land and ice lying to the north, west, and east. The Grantsburg Sublobe acted as a dam to the south, and for a short time Glacial Lake Grantsburg was formed. As the melting Grantsburg Sublobe broke up in the area of Taylors Falls, the lake began to drain to the south (Fig. 2). Meltwater from the north and west, however, was forced to flow along the periphery of the Sublobe to reach this exit (Fig. 2b). For some of this meltwater, the dominant direction of flow was actually from southwest to northeast. Water flowed through, around, and over the melting Grantsburg Sublobe, depositing a well-sorted sand.

As the Sublobe decayed still further, the dominant path of meltwater flow shifted to a northwest to southeast direction (Fig. 2c). The Mississippi River, or at least a forerunner of it, was carrying large volumes of meltwater from the northwest.
across, around, and through the decaying Sublobe. When the Sublobe had finally completely melted, a large expanse of wet sands remained, in many places overlying buried remnants of ice (Fig 2d). The CCNHA lies in what Cushing called the Bethel Outwash Plain; the trend of the landforms on this plain is northwest to southeast.

Vegetation, including forests of spruce and tamarack and areas of open sedge, became established on the wet sands. Higher and, therefore, dryer portions of the area may have supported aspen forests and even prairie grassland. The land surface was unstable, however, and as buried blocks of ice slowly melted, former hills became depressions and even lakes; former lakes and wet depressions dried as the water table dropped because of both melting of the ice blocks and downcutting of streams.

Even after all of the buried ice had melted and the water table had dropped to a level similar to that found today, the landscape continued to be somewhat unstable. During very dry periods, the most pronounced of which occurred about 8,000 years ago, vegetation would "lose its grip" on some sites and the sands would blow, forming dunes. This probably happened more than once during the history of the Anoka Sand Plain and of CCNHA. For example, Allison Savanna, on the southern border of CCNHA, clearly shows evidence of dune activity.

This chronicle brings us to the present, and CCNHA as we now find it. Over the past 10,000 and more years, the geologic material (sand) originally deposited by the meltwaters and subsequently modified by the wind interacted with the present topography, including the position of the water table relative to the land surface, and with the cumulative effects of vegetation growing on the material, to produce the pattern of soils that we now find (Fig. 3). In the view of a soil scientist, then, a soil begins as a uniform deposit of geologic materials. As the factors as described above interact, the uniform material begins to become heterogeneous. It differentiates into horizons or layers that are parallel to the earth's surface. The properties of each layer, and their arrangement, provide clues to the interacting factors of soil formation.

Rather than abstractly talking about soils and their properties, soil scientists give names to soils. The names are usually derived from a local town, river, lake, or other significant feature occurring near the location where a representative example of that soil is found. Each name refers to a certain soil with a unique sequence of horizons. The sequence and properties of the horizons are similar in soils of the same name.

One of the major upland soils at CCNHA is the Nymore soil, or a soil that is very similar to the Nymore. It covers about 13% of CCNHA (Fig 3). The Nymore soil has primarily formed on broad, smooth flats in sandy materials. The feature that distinguishes it from other soils of CCNHA is the surface horizon, which is thicker and darker than that of other upland soils at CCNHA. That horizon is usually about 30 inches thick, and is dark grayish brown. The thickness and color indicate that this soil formed under either prairie or savanna vegetation containing an abundance of prairie grasses. The landscape of the Nymore soil is ideal for frequent and extensive fires that would restrict growth of woody vegetation.

Another major soil at CCNHA, occupying about 9% of the area, is the Sartell soil (Fig. 3). It is most often found on undulating excessively dry portions of the area, and is usually found in areas with evidence of previous dune activity. In a
GENERAL SOIL MAP
Cedar Creek Natural History Area, Minnesota

Soil Associations

1. Nymore association: Dark-colored, level, excessively drained soils formed in medium sand-textured outwash sediments.

2. Rifle-Lupton association: Dark-colored, level, very poorly drained soils formed in thick deposits of organic soil materials.

3. Sartell association: Light-colored, undulating to hilly, excessively drained soils formed in fine sand-textured outwash and aeolian sediments.


(Map “Cedar Creek Natural History Area and Environs” prepared by Mark Hurd Aerial Surveys, Inc. was used as a base map.)

Figure 3. General soil association map of Cedar Creek Natural History Area (from Grigal et al. 1974).

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sense, this soil has formed on “blow” sand, or sand from which finer particles have been removed by wind. The surface is thin and light colored. Because of its low fertility and droughtiness, vegetation growing on it is usually sparse and does not contribute dark-colored organic matter to the surface as in the Nymore soil.

The dominant upland soil in CCNHA is the Zimmerman soil. It covers about 37% of the area (Fig. 3). The soil is extensive because it has formed under the action of the dominant soil-forming factors of CCNHA. That is, it has formed on undulating topography under oak forest with an admixture of grasses, and in sandy material that has not been disturbed since it was deposited by flowing meltwaters. In a sense, then, the Zimmerman is the typical soil of CCNHA. It, too, has a thin light-colored surface. Deeper in the soil, usually from about 35 to over 60 inches, thin layers or bands of finer sands, some with clay in them, are found. These bands are considered by some to be remnants of the stratification of deposits from the flowing meltwaters.

Two other soils in CCNHA are considered to be related to the Zimmerman soil, but paradoxically their properties are dissimilar to those of the Zimmerman soil. Although each soil, the Lino and the Isanti, only occupy about 4% of the area, their occurrence is very predictable. They form a catena with the Zimmerman soil. The Latin word catena means chain, and each of these soils forms a link in a topographic chain from upland to lowland in CCNHA (Fig. 4). The Zimmerman soil is a well-drained soil that is found on higher
positions of the landscape; the water table is always deeper than 40 to 50 inches from the surface. The Lino soil occurs further down a hypothetical slope (Fig. 4). This soil has a surface that is about 8 inches thick and dark-colored. In most years, the water table reaches to within about 30 inches of the surface, and as a result, the lower horizons of the soil have mottles, or variegated colors, indicating presence of chemically reducing conditions. The Isanti soil is found even further down the slope (Fig. 4). The water table is at or very near the surface of this soil during at least some part of the growing season. As a result of the wet conditions, the surface, about 10 inches thick, is very dark and high in organic matter.

This catena of mineral soils ends with another major group of soils in CCNHA, those that did not form in material that was deposited by melting waters. Instead, these soils have formed in deposits of partially decomposed organic material, or peat. They are found in the extensive fens or peatlands that occur in the area. Their formation is a result of the subdued topography and the high water table in many areas of CCNHA. As plants grow in saturated environments, their residues only partially decay and slowly accumulate to form peat. Organic soils occupy about 23% of CCNHA. They also form a catena, or at least a sequence of soils that differ in properties related to periodicity of saturation.

The Markey soil is of very minor extent in CCNHA, occupying only 2% of the area. It can be considered to be a member of a Zimmerman-Lino-Isanti-Markey catena, in that it occurs in even lower topographic positions than does the
This diagrammatic map shows the interspersion of habitat types and the network of streams and roads that transect the Cedar Creek Natural History Area.
Isanti soil (Fig. 5). The surface of the Markey soil is well-decomposed peat. It forms a horizon from 20 to 50 inches thick over sandy material. It is well decomposed, with less than one-third of its volume including recognizable plant fibers. In most years, the water table is at the surface of the Markey soil.

When the horizon of well-decomposed peat is deeper than about 50 inches, the soil is named the Seelyville. It, too, is of limited extent in CCNHA, occupying only about 3% of the area. The presence of well-decomposed material indicates that although the Markey and Seelyville soils are very wet, conditions are moderately favorable for decomposition of plant material. This may indicate that occasionally these soils dry out sufficiently for decomposition to proceed.

In the Rifle soil, another organic soil, the peat, is also deep, but it is not as well decomposed as in the previous two soils. One- to two-thirds of the peat is composed of obvious plant fibers that have not fully decomposed. This may indicate that the Rifle soils do not experience periodic drying, but are continuously wet. About 12% of CCNHA is Rifle soils (Fig. 3).

Both the Seelyville and the Rifle soils are presumed to have formed from plant debris of a predominantly herbaceous origin, including reeds, sedges, and cattails. The last important organic soil in CCNHA is the Lupton soil. It, too, is formed from deep and well-decomposed peat, but it differs from the Seelyville in that the origin of the plant material from which it has formed is predominantly woody, or from forest vegetation. The white-cedar forest that surrounds Cedar Bog Lake occurs on the Lupton soil. The Lupton soil covers about 6% of CCNHA (Fig. 3).

I have briefly discussed these soils of CCNHA from the perspective of a soil scientist, wherein the soils are partially the product of the vegetation. Yet we cannot forget the perspective of the botanist, wherein the vegetation is partially a product of the soils. Can we sort out this apparent paradox? No, nor should we. It clearly indicates the intimate and interacting nature of the entire ecosystem, including vegetation, soils, and fauna. No single element can really be understood unless its interactions with other elements of the system are also understood.

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Indian grass, shown in the foreground, is one of the most important species in Cedar Creek prairies. Big bluestem, little bluestem and needle grass are the other dominant native grasses.
The nymphs of a black and yellow species of dragon-fly come out of Cedar Bog Lake and much larger Fish Lake in mid-May. They climb the sedges along shore and split open to free the winged adults for a spectacular flight period.

Photo by Alton A. Lindsay

**Adventures With Insects**

God in his wisdom made the fly and then forgot to tell us why . . . Ogden Nash

JOHN HAARSTAD*

**SIMILAR SENTIMENTS** probably fly through the minds of most field workers at Cedar Creek during the summertime. A succession of blood-seeking species of mosquitoes, black flies, horse flies, and deer flies fill fields and woods from late April to first frosts. Most oppressive and impressive are the deer flies. During much of July, field work becomes a contest of wills between flies and researcher. The flies generally win. I've captured and crushed literally quarts of deer flies by sweeping my insect net over my head while strolling through bur oak savanna. No market has yet been developed for deer flies, so they are discarded on the ground to become fodder for foraging thatch ants.

The aggressive ants (*Formica obscuripes*) are equally impressive. They dominate the terrestrial realm in their unrelenting quest for food. One committed researcher, Jeff Brokaw, was obliged to visit a local hospital after being mauled by these ants. His ankles were badly bitten and formic acid was sprayed into the wounds while he intently watched other thatch ants tend honeydew—secreting caterpillars on bur oak. Given this hostile environment, one may wonder how much is known of the insects inhabiting Cedar Creek.

**THE CEDAR CREEK INSECT COLLECTION**

Henry Townes, a world-renowned specialist on the Ichneumonidae (a family of Hymenoptera parasitic on other insects), makes a rather interesting comparison between birds and these parasitic wasps. Both have comparable global diversities (ca. 8000 species), yet birds comprise the entire
vertebrate class Aves and are the subject of numerous ornithological courses. The Ichneumonidae, one of nearly 80 families in the Order Hymenoptera (ants, bees, wasps, etc.) receive but passing attention in most Entomology courses. If your biology needs refreshing, the phylogenetic hierarchy is Kingdom, Phylum, Class, Order, Family, Genus, Species. Within the family Ichneumonidae, differences can be found that are as great as those between pelicans and hummingbirds. Another well-known scientist, J.B.S. Haldane, when asked what he thought of God's Creation, felt that the Creator "showed an inordinate fondness for beetles." Indeed, of the one million forms of life (from molds to man) described on this planet, 30% are beetles. There are perhaps two million more species still undiscovered and the vast majority of these are insects.

I am frequently asked, "How many species of insects are on Cedar Creek?" My conservative response is 5,000, but perhaps a truer estimate would be 10,000 species. The insect collection at Cedar Creek contains some 30,000 specimens and about 2,500 species. More than 500 species of beetles have been collected and identified, but this number represents perhaps but a quarter of the species to be found here. Some groups, like the butterflies, dragonflies, and grasshoppers, have been well collected, but many groups (for example, chironomid and Cecidomyiid midges) have scarcely been explored. It is unlikely that the insect fauna of Cedar Creek will ever be completely catalogued. While this may be discouraging to some, I am quite obsessed with enlarging the Cedar Creek collection—perhaps because there are always new species to be found.

While the insect fauna of temperate North America is, as a whole, well studied, few locales have received as much attention as has been given to Cedar Creek. Intensive collecting may turn up species unknown to science, and certainly provides range extensions for existing species. Records of plant hosts and insect prey and observations on behavior add to our knowledge of individual insect life histories. The Collection also serves as a valuable reference resource for research being conducted at Cedar Creek.

CURRENT RESEARCH

Ecological studies of insects can provide insights into patterns we observe in the biological world. Does grasshopper diversity vary with field age, vegetation composition, or soil fertility? What effect does the presence or absence of thatch ants have on the insect community inhabiting bur oak? Why do males of some species of dragonflies defend mating territories against males of other species? What factors affect oviposition site selection in the black blister beetle, Epinotia pennsylvanica? Larvae of this beetle feed on the egg pods of grasshoppers, and the adults feed primarily on the pollen of goldenrods. Do adults oviposit near larval or adult resources? What effect does the diversity of odors (plant chemicals) in a plant community have on specialist herbivorous insects attempting to colonize a plant? For example, is the goldenrod gall fly repelled from patches in which goldenrod is interspersed with a strong-smelling plant such as mint? What effect do two herbivores have on each other if they feed on the same plant? These are some of the questions currently being addressed by researchers at Cedar Creek.

A study of the interactions between two herbivores is being explored by Sharon Strauss. She has uncovered an interesting case of herbivory on smooth sumac (Rhus glabra) involving two species of beetles. Larvae of the flea beetle (Blepharida rhois) defoliate clones to the extent that no leaves remain at the end of the season. The sumac responds by sending up basal shoots. These young green shoots are very attractive to the longhorn beetle (Oberia ocellata). Adults girdle the tender shoots, lay eggs, and the larvae bore into the pith. Thus, we find that sumac defoliation by one herbivore, the flea beetle, actually creates a resource used by a second herbivore.

My research interest is in unravelling the niche relationships of coexisting, potentially competing species. It is a basic, some say tautological, tenet of community ecology that no two species in a community can occupy the same niche. To put it another way, if several similar species are found to coexist, they must use different resources or their numbers must be limited by different factors. I am currently working on the niche relationships of some 20 species of ants inhabiting CCNHA old fields, but below I give an account of two earlier endeavors.

WATER LIZARDS AND MEGANEURA

It was not until the 1600s that Swammerman "officially" made the connection between water lizards and dragonflies. Prior to this time, water lizard referred to the aquatic stage of dragonfly life. Perhaps Medieval man would have been more attentive had he lived 300 million years ago when dragonflies such as Meganeura with 3-foot wingspans soared the skies in search of prey.

Dragonflies (5,000 species) and damselflies (3,000 species) are among the more primitive of winged insects, and together comprise the insect order Odonata. Both aquatic larvae and adults are voracious predators. Larvae of some of the larger species can wreak havoc in fish hatcheries and adults of a few species have been known to decimate honeybee hives by picking off returning workers. However, the tonnage of Diptera pests that dragonflies consume and the food dragonfly larvae in turn provide for larger fish, far outweigh the minimal damage they are suspected of causing.

During one of my first visits to Cedar Creek, I witnessed an enormous dragonfly emergence on one of the Area's lakes. Fish Lake is a 134 hectare, shallow body of water that supports tremendous populations of dragonfly larvae. I found that three species of dragonflies were emerging simultaneously and I wondered how all three could coexist in Fish Lake in such numbers. Unravelling the niche relationships of the dragonflies inhabiting CCNHA became the subject of my M.S. thesis. Over the next few years I collected 43 different species of dragonflies on the Area. This represents one half of the species known for the entire state of Minnesota. I noted differences in larval morphology and habitat preference, as well as differences in adult flight seasons, feeding habits, and foraging habitats.

Here I wish to confine attention to the three species that
emerged so abundantly from Fish Lake. The three species involved belonged to three different families of Anisoptera. The larvae of these three species are morphologically very distinct and select different substrates for foraging. The gomphid (*Gomphus spicatus*) is a flattened, wedge-shaped burrower found in sandy regions of the lake. The libellulid (*Libellula julia*) is a hairy, robust sprawler in fine sediments under lily pad canopies. The cordulid (*Epitheca spinigera*) is a long-legged, prettily-patterned clamberer over coarse detritus substrates. As adults, *Gomphus* feeds from perches in fields, *Libellula* feed from perches in wooded habitats, and *Epitheca* feeds continuously on the wing on “aerial plankton” carried from the woods by the wind. Thus, both as larvae and adults, these three species appear to have nicely complementary life histories.

But why should all three species emerge simultaneously from Fish Lake in late summer? Emergence is explosive. That is to say, literally millions of individuals leave the lake in a matter of a few days. So many individuals attempt to emerge during this short period that those in the process of exiting their larval skins are trampled by compatriots that are searching for emergence supports. If their delicate unexpanded wings are torn, they will plummet into the lake on their fateful maiden flight. Others are unceremoniously knocked into the water. At the end of the day, the shallow margins of the lake are literally covered wit dead and dying dragonflies.

I have placed emergence screens along the margin of the lake to obtain some measure of the magnitude of the emergence and the extent of trampling that occurs. The screens intercepted roughly 10% of the emerging populations, but even so, a heavily used 10-foot screen would often have more than 1,000 larvae after a single day of emergence. On such screens, trampling mortality was often in excess of 90% and affected all three species. The fewer the number of individuals attempting to emerge on a screen, the more likely they were to emerge successfully. This prompts one to ask “Why do these three species emerge so explosively when by doing so, the probability of an individual emerging successfully is actually reduced?” To put in anthropomorphically, if you’re slow and blind and not in a hurry, it is probably wiser to avoid morning Rush Hour and cross the freeway during midday. My guess is that these dragonflies are in a hurry. The first individuals to leave the lake are the first to deposit eggs and have their larvae hatch and begin to feed. Dragonfly larvae are notorious cannibals. I cannot keep large...
and small larvae in the same container for the smaller are quickly decapitated by the larger. I believe that these species run the emergence gauntlet because to do otherwise would mean dropping eggs into larval-infested waters. Perhaps you have a better idea.

THINGS THAT GO ZIRP IN THE NIGHT

One of the more interesting fates that can befall a dead mouse is to be discovered by burying beetles. These remarkable insects, nearly one inch long and brightly patterned in orange and black, find and bury small carcasses which serve as food for their larvae. If one lives in a rural wooded area, one has only to place a freshly dead mouse on forest litter and return with flashlight periodically that very same night. In all probability, a number of burying beetles will discover the carcass. What then transpires is fascinating. Individuals will climb atop the mouse or crawl beneath it attempting to move it. Burying beetles are rather strong and can move a mouse a couple of yards during the course of a night, so it is wise to tether the mouse if you wish to keep track of where it is going. Frequently, one hears the insects “zirping” as they rub their abdomen against the underside of their elytra, and it is said that this is to call in a potential mate. If a number of beetles have assembled at the carcass, one will observe chases and fights between individuals of the same or different species. Eventually a pair of beetles, male and female, gain control of the booty, and they proceed to bury it by excavating the soil beneath. This task frequently requires all night.

Once the mouse is concealed below ground, the beetles cut off its hair with their mandibles and roll the mouse into a ball. Presumably the removal of hair gets rid of any blowfly eggs that might have been deposited on the mouse prior to burial. The female then excavates a tunnel away from the burial crypt and deposits one to two dozen eggs. Three days later, the eggs hatch and the larvae crawl back to the mouse “ball.” During the interim, the male and female have been busy molding the ball, chewing a cavity in the top of it, and applying anal secretions to it. These secretions probably serve as some sort of embalming fluid—preserving freshness and preventing molds from developing. The newly hatched larvae, having reached the mouse ball, crawl into the cavity at the top, and more remarkable skill, the female and male feed them by regurgitating predigested carrion to them. As the larvae grow larger, they feed more frequently on the mouse carcass, although occasionally even large larvae will receive regurgitate from the mother.

Larvae do not require parental regurgitate to develop, for I have successfully hatched and reared larvae from eggs without their parents in attendance. However, parental presence is probably important in protecting offspring from potential predators. Even as I peek at developing broods in laboratory containers, the agitated parents begin zirping and turning the mouse ball over hiding larvae from view. A raccoon, fox, or mole discovering such a treasure, is likely to laugh at this gesture and gobble up the whole thing, but parental protection may be quite effective against

CEDAR CREEK
NATURAL HISTORY AREA
HAS BEEN DESIGNATED A
REGISTERED NATURAL LANDMARK

THIS SITE POSSESSES EXCEPTIONAL VALUE
AS AN ILLUSTRATION OF THE NATION’S NATURAL
HERITAGE AND CONTRIBUTES TO A BETTER
UNDERSTANDING OF MAN’S ENVIRONMENT

1975
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR
invertebrate predators. I introduced a predatory ground beetle, the fiery caterpillar hunter, into a rearing chamber containing a female beetle and 16 offspring. The ground beetle quickly ate two of the larvae, but the agitated mother attacked and snipped off four of the ground beetle's legs. If no mishap befalls the larval brood, they are fully developed after one week of feeding. Larvae burrow into the soil, pupate, and emerge as adults 20 to 40 days later.

My reason for studying burying beetles was not so much their amazing behavior, but rather the question, "do different species compete for resources, and if so, how do they partition resources so as to minimize this competition?" While pitfall trapping for ground beetles, I accidentally trapped a shrew. The dead shrew attracted three species of burying beetles. The observation that three different species were attracted to the same kind of carrion posed an interesting problem of coexistence. After a couple of years of trapping in various habitats (field, woods, marshes), and throughout the summer (April through October) using different kinds of baits (frogs, snakes, birds, mice), a pattern began to emerge.

I found that eight species of burying beetles (*Nicrophorus*) inhabited Cedar Creek. This number is itself quite amazing for there are only 15 species of *Nicrophorus* in all of North America. I did not expect the beetles to be too particular about the kind of carrion they buried—and they weren't. All that most required was that it be small enough to bury quickly and in relatively "fresh" condition. However, species did differ considerably in the habitats they searched for carrion and the season of the year they were reproductively active.
Two species searched for carrion in abandoned fields. One (N. obscurus) was active in early spring and the other (N. marginatus) was active throughout the summer. One species (N. vespilloides) was the only species to use marshes extensively. Five species foraged primarily in wooded habitats. One (N. sayi) was active in the spring, one (N. tomentosus) in the fall, and the remaining three were active in mid-summer. Untangling the niche relationships of these three species proved to be more difficult. However, I found that one (N. pustulatus) was primarily arboreal (i.e., came to baits placed in trees). The other two searched for carrion on the ground. One (N. orbicollis) is considerably larger than the other (N. defodiens), and when I had these two species compete for carrion in the lab, the larger N. orbicollis always killed the smaller N. defodiens. However, defodiens was able to raise a brood on small carrion such as shrews (Sorex) which were not very attractive to the larger orbicollis. Thus, a combination of habitat, season, foraging location, and carrion size all appear important in reducing competition among coexisting species of Nicrophorus.

CONCLUDING REMARKS

I hope these glimpses into insect life have given the reader a sense of the challenge and excitement I and other researchers have experienced studying insects at Cedar Creek. All too often, visitors to Cedar Creek confine their questions to bear, coyotes, deer, fox, and hawks. Most are unaware of the grand struggle for existence being performed in miniature right under their very noses.

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CEDAR BOG LAKE IS A SMALL BOG LAKE in central Minnesota. It is characterized by turbid waters, very high organic matter content, and interminable mosquito populations. It is also the site of a research program that has been more or less active since the mid-1930s. Some of the early research suggested that the bog lake was filling in or growing toward the center at a rather rapid rate. A discussion of recent studies of Cedar Bog Lake provides an opportunity to see how peat systems function, and to address the question of the fate of Cedar Bog Lake.

Geologically, peatlands resulted from Minnesota's momentous glacial history. Glaciers leveled the land, and inhibited rapid water flow. By doing so, they created an environment optimal for peatland formation and organic matter accumulation. Glacial activity had other consequences important to this discussion: the glaciers scoured small basins all over the North country. During glacial retreat, these pockets remained filled with ice. As the ice block melted, there remained “ice-block lakes,” which are widespread in today's landscape. Ice block lakes that have retained their original character are part of Minnesota's glory. Many others have become water islands in a morass of peat. They also are glorious in their own way.

While traveling through the state's peatlands, you may have noticed their second most striking feature—the flora. Their first resounding feature is the fearsome insect population. However, with fortitude and repellent, one is afforded the opportunity to find brilliant green mosses, fascinating
carnivorous plants, stark black spruce, and many other interesting, water-loving species. The characteristic vegetational complex that comprises Minnesota's peatlands has been extensively studied. As a result, vegetative cover often can be used to characterize peatlands as "bog" or "fen." The differences, as we shall discuss, are important in the issue of potential lake fill-in processes.

Typically, a "fen" (minerotrophic peatland) receives significant amounts of groundwater inputs. These inputs are comparatively rich in nutrients, and have a relatively high pH. Fen water pH's typically range from 6 to 7.5. A "bog" (ombrotrophic peatland) is primarily fed by precipitation, which is iron-poor, or very dilute. Sphagnum moss and other acid-loving plants are characteristic of bog sites. These plants aid in maintaining bog water pH's at 3 to 4 through cation-exchange and production of organic acids. Peat from bogs is mined for fuel and horticultural purposes. Fen peat does not have the qualities desired for commercial uses.

These two categories, fen and bog, are broad, and encompass a range of characteristics pertinent to peatland description. In spite of their breadth, plant cover characteristics can usually be used to classify a site. For example, Northern white cedar, sedges, or tall shrubs are indicators of fen areas. Bogs provide a less optimum environment for tree growth and support low shrubs, short scrubby black spruce, and large open areas with only Sphagnum moss. Both bog and fen support black spruce and tamarack. The differences are more apparent in growth, height, and vigor than in species.

An interesting feature peculiar to both fens and bogs is the amassing of organic material. In most terrestrial and aquatic systems, plant material decomposes about as rapidly as it is
The habitat on the Cedar Creek Natural History Area is about a third forest, a third wetland, and a third open field and Prairie. Forests range from white cedar stands in low, wet sites, shown in the foreground, to stands of pines and oaks, or sugar maple and basswood on the uplands. Wetlands vary from open cattail marsh, to floating bogs characterized by sedges and swamp loosestrife. Croplands, abandoned fields and undisturbed savannah and tall grass prairie, shown in the upper right, are widely distributed over the area.

The valley of Cedar Creek showing islands of forest surrounded by marsh. Photo by David F. Gregal

produced. The decomposition process provides energy and nutrients for many insects and other animals and drives a system known as soil genesis or soil formation. Thus, soils consist of mineral matter overlain by decomposing plant material. The amount of plant material stays fairly constant year after year.

However, the slow rate of water movement through fens, and the high water storage capacity of bogs, inhibit decomposition of dead plant material. Unlike the mineral soils of upland forests, peatland soils are highly organic and contain large quantities of plant material which are in various stages of decomposition. In most peatland sites, there is an accumulation of new organic matter year after year; i.e., the soils are growing comparatively rapidly.

Cedar Bog Lake, part of a fen site, is a small ice block lake in a peatland. It is located within Cedar Creek Natural History Area about thirty miles north of the Twin Cities. The vigorous vegetation that surrounds the lake, and the animals that live in the fields swamp and lake invite study. They have been studied for over fifty years. In the 1930s, Raymond Lindeman studied the flora and fauna of Cedar Bog Lake, as well as surrounding emergent and terrestrial vegetation. Emergent plants obtain nutrients from the water, but their leaves remain high above the water surface in the fall. Lindeman synthesized, in words and mathematical equations, how plants and animals interacted, and how their interaction via production and consumption of food calories might shape the lake’s future structure and function.

In the thirties, when Lindeman waded through collections of aquatic plant material and benthic fauna, the entire lake bottom was densely covered by plant growth. Various pondweeds such as coontail (Ceratophyllum demersum) and Bushy pondweed (Najas flexilis) were abundant. Cattails surrounded the lake during drier periods, but later, during wetter years, swamp loosestrife (Decodon verticillatus) took hold.

Clearly marked concentric rings of vegetation surrounded the lake in 1930, and do today. The composition and width of the zones has changed dramatically, however. Murray Buell, who worked with Lindeman in the ’30s, noted that the rings consisted of in-lake plants, followed by tamarack, northern white cedar, and then, deciduous species such as basswood and maple. Today, the same species are present, yet not with the same frequency or density. Little submerged aquatic vegetation is found in the lake, except at the margin. Concentric zones of tamarack and cedar grow closer to the lake’s edge. Swamp loosestrife borders over half of the lake perimeter.

More interesting, perhaps, is the story told by the soils formed under the living plants, and the sediment accumulating at the lake bottom. Lindeman measured cores of soils and lake sediments along a transect from the outer edge of the forest, across the swamp across the lake, and out to the opposite edge of the forest. Examination of his core samples revealed that at one time, the lake was much larger.

Lindeman learned that Cedar Bog Lake had been gradually

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filling in since the glacial retreat. During dry periods, such as during Lindeman’s time, the cattail and swamp loosestrife, were advancing toward lake center. This encouraged Lindeman to predict that the lake would fill in within 250 years: a rate of 0.2 metres per year. However, Murray Buell, a Lindeman co-worker in the early thirties, measured the distance, from a benchmark through the floating mat vegetation, to the lake’s edge. In 1968, he remeasured the transect length and found little or no decrease in the size of the lake during the 35+-year period; i.e., little or no movement of the vegetative mat toward lake center.

We have developed a third assessment of the rate at which the land moves toward lake center, or the rate at which the lake is filling in. Measurement of five aerial photographs taken between 1938 and 1983 revealed that lake size had decreased from 14,000 square metres to 12,600 square metres. That is a rate of advancing toward lake center of 0.03 metres per year. At that rate, the lake will fill in within 2,000 years.

Death and sedimentation of algae and submerged plants within the lake augment the lake fill-in process, and may even exceed the rate of encroachment of the edge mat. We do not have accurate measurements of these rates, but we expect the rates to be high. A major variable, which is less predictable, is change in groundwater inputs, and resulting fluctuations in lake water level. These changes will also influence the rate at which Cedar Bog Lake fills in. In fact, if the lake became isolated from the groundwater, the whole lake could rise as organic matter accumulates at the bottom. Such a process results in peatlands described as raised bogs. Lakes, as part of raised bog systems, also rise with respect to the accumulating sediment at lake bottom. Thus, in this case, the lake has risen and the sediment cores reflect differences over time. Lake fill-in was not the vehicle of change, but the measurements in sediment cores may be similar and the differences difficult to detect without measurements of the groundwater.

Thus, the question remains: Is Cedar Bog Lake filling in, or is the whole lake rising? Undoubtedly, evidence from Lindeman’s core samples support the idea of lake fill-in. Under the present swamp loosestrife mat, partially decomposed vegetation from the mat edge lies over lake sediment. That may imply that the mat is encroaching on the lake. The aerial photos also indicate that lake area has decreased over a fifty-year period. Yet, with regard to an overall rise of the fen area, and potential changes in groundwater inputs, measurements are still required. It does appear that Cedar Bog Lake is becoming smaller, and that is probably typical of many Minnesota bog lakes. The cause may vary with each lake, and remains to be determined for Cedar Bog Lake.

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Field Instruction in Prescribed Burning Techniques at the University of Minnesota

FRANK D. IRVING*

Spring fires have been used on the Cedar Creek Natural History Area in Anoka County, Minnesota, since 1964 to restore and maintain about 500 acres of natural habitat for scientific and educational purposes. In the six spring burning seasons from 1965 to 1970, a total of 108 seniors majoring in forestry or wildlife management have earned academic credits by participating in burns covering 1,245 acres which were conducted on 19 dates.

This paper describes the area which is being managed by fire and outlines the procedure used to adapt this effort for educational purposes.

The Cedar Creek Natural History Area has a total area of about 4,500 acres and is administered by the University of Minnesota and the Minnesota Academy of Science. Under the leadership of Dr. William H. Marshall, Director of Field Biology and professor of wildlife management, a decision was made in 1963 to initiate a program of systematic prescribed burning on a portion of this area to compensate for the influence of effective forest fire protection which had essentially excluded wildfire as an ecological factor. This selected area, which is now being expanded to 800 acres by the acquisition of privately owned tracts, is on the Anoka sand plain about 30 miles north of Minneapolis. It has sandy upland soils and shallow peat over sand on the poorly drained lowland.

The major upland cover type on the fire managed area is a mixed oak forest similar to the xeric forest of southern Wisconsin. Hill’s oak and bur oak contribute approximately 110 and 23 square feet of basal area per acre respectively to the mixed oak stands which cover 60 percent of the unit. Old fields with a thin stand of June grass, little bluestem, big bluestem and other grasses and forbs cover 25 percent of the area. The remaining 15 percent is marsh with cattail, sedges and associated lowland plants. The history of land use before purchase included grazing, wood cutting, farming and burning. Before settlement, the original vegetation undoubtedly contained many oak openings. Complete protection from cutting, grazing, and fire has allowed a heavy understory dominated by hazel and other shade tolerant hardwoods to develop.

To restore these oak stands to an approximation of the savanna recorded by early travelers, the Cedar Creek prescribed burning unit has been divided into 14 compartments which vary from 10 to 80 acres in area. Where roads or truck trails were not available for compartment boundaries, a tractor and disk constructed narrow fire breaks. The following treatments are being tested:

1. Annual burn.
2. Two burns—one year rest.
3. Two burns—two years rest.
4. Three burns—three years rest.
5. Four burns—two years rest.
6. One burn—five to eight years rest.
7. Control (no burn).

Surface fuels now vary considerably within compartments reflecting present cover types, past land uses, topography, and recent fire history. After the first burn in each compartment, the surface fuels are generally light (oak leaf litter in the woods and cured grass in the fields).

In the six spring seasons from 1965 to 1970, class size has varied from 4 to 32. The students who registered for problem credit were seniors. All of the forestry majors had had some classroom and field instruction in fire control, and many of them had had limited fire control experience while on summer jobs. The wildlife students were also seniors, but few had received any classroom instruction in fire and few had job experience which exposed them to fire control tools and methods. Since this course was offered on an elective basis, only students with interest and curiosity registered. When asked why they wanted to participate, most indicated that they wanted to learn how to handle fire so they could use it in their future careers as land managers.

Experience has evolved the following approach: During the first week of the spring quarter, the class assembles for a briefing session in which the objectives and methods of burning at Cedar Creek are explained. Each class is divided into four crews and crew assignments are made for each compartment to be burned. When a crew is assigned to fire behavior they take weather observations, compare observed
values to those forecast earlier, and watch changes in rate of spread, fire intensity and smoke characteristics. The ignition crew handles the firing, under the guidance of the instructor. The holding crew, using hand tools, suppresses any spotfires or crossovers. The patrol and mop-up crew watches the cool sectors of the perimeter as firing progresses and puts out special hazards near the line which might produce a spotting problem if the wind increases before they burn out.

The instructor follows the fire weather and fuel conditions until satisfactory conditions for burning develop. Fire danger data from the Carlos Avery district office of the Division of Lands and Forestry, Minnesota Department of Conservation (6 miles southeast of Cedar Creek) are used for this decision. Burns have been conducted in the buildup index range of 7 to 32. Higher values would be acceptable, but they have not occurred during the seasons when the classes were ready to burn. Fires have been started with wind velocities as high as 20 mph, but the 8-12 mph range is preferred. Early season fires commonly begin with air temperature in the 50-65 degree F range and later fires with 70-85 degrees F. Relative humidity at ignition has ranged from 25 to 45 percent, but 30 to 40 percent is preferred. By taking advantage of the variation in fuels and selecting different burning conditions and herbaceous stages it is possible to demonstrate a wide range of fire behavior.

To avoid conflicts with part-time job commitments of students, burns are not scheduled on weekends. Fridays are used only when time is running out near the end of the spring quarter. By using only 4 days per week, the 5 week season is reduced to only 20 possible days for burning; and unfavorable weather generally reduces this to from 3 to 8.

When conditions appear to be satisfactory for a burn, a weather forecast is requested from the Minneapolis office of the Weather Bureau, Environmental Science Services Administration. Crew leaders are informed before noon, and the crews assemble in the field at 4:30pm to draw equipment and discuss the plan.

Mr. Alvar Peterson, resident manager of the Cedar Creek
Natural History Area, prepares the hand tools (fire rakes, shovels, back pack pumps, and swatters) and is present during each burn with a wheel tractor equipped with a pump and pulling a trailer with water barrels and extra hand tools. Mr. Peterson also obtains the necessary burning permit and assumes responsibility for patrol and mop-up after the crews are released.

When the tools have been distributed and the crews briefed, ignition begins with a test fire on the lee side in a corner of what will become the base line. If the test fire behaves satisfactorily, the base line is backfired and a narrow strip head fire is set. During this phase of the operation, the ignition crew is expected to watch the fire behavior and coordinate its action with the holding crew. The width of successive strip head fires is adjusted to the existing wind and fuel conditions. Since the usual class size in recent years has provided two or three times the number of people needed to handle a burn safely, students on all crews have a chance to observe and interpret the influence of fuel and weather variables on fire behavior.

The holding crew generally has very little to do if the ignition crew is doing its job well. However, some weak spots in the fire breaks, occasional wind shifts, and excessive strip widths with head fires can produce problems. When a spot fire occurs, the nearest member of the holding crew takes direct action and calls for help if needed. The holding crew follows the progress of ignition and reacts to the fire. Whenever possible, the members of the holding crew are encouraged to examine the compartment before the date of the burn to inspect the lines and identify fuel problems (inside and outside the burn) which might require special attention.

The patrol and mop-up crew watches the base line until it cools down, then takes over the flanks as firing progresses. Whenever smoke reduces visibility on roads, members of this crew station themselves on the road and warn motorists. They also answer questions about the burn. (This is one important way to reduce negative public reaction to burnings.) The mop-up effort is usually limited to a few spots close to a fire break, such as hollow standing trees or stumps which might provide brands for spot fires. All crews are generally released by 9pm and are often finished by 7pm if only one compartment is burned in an evening.

Several features of this instructional effort appear to contribute to its success:
1. A broad objective of burning, a flexible fire prescription, and a relatively long spring fire season makes it possible to schedule three or four burns in spite of schedule
conflicts and other restrictions.
2. The burn compartments are large enough to include significant variation in fuel types but small enough to be burned in about 1 hour.
3. The natural area maintenance objective requires repeat burns and allows the accumulation of experience with individual blocks.
4. The fuel and weather conditions involved are safe enough to allow the use of bad examples as a teaching technique.

This effort is designed to introduce future land managers to the tools and techniques of prescribed burning. It stresses simple concepts and reinforces these through field application and repetition. The brief written reports and evaluations received from the students suggest that they obtain some knowledge of fire use as well as some elementary skills. These evaluations also indicate positive attitudes toward fire use and the associated problems. As with any instructional effort, however, the final measure of success has to be the performance of the students, and time will provide this measure.

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CEDAR CREEK
NATURAL HISTORY
AREA
UNIVERSITY OF MINNESOTA

WHAT IS CEDAR CREEK? The Cedar Creek Natural History Area is a 5,460 acre research facility operated by the University in cooperation with the Minnesota Academy of Science. It is located in Anoka and Isanti Counties about 30 miles north of Minneapolis on US Highway 65. The area contains a unique blend of forests, prairies, marshes, lakes, ponds and agricultural fields of various ages since abandonment.

HISTORY. Cedar Creek, established in 1940, was designated a National Natural Landmark by the National Park Service in 1975. In 1977 it was included as an Experimental Ecological Reserve in a proposed national network, and in 1982 it was one of 11 sites in the United States selected by the National Science Foundation for funding of Long-Term Ecological Research.

The first 500 acres were acquired by the Minnesota Academy of Science through a purchase and gift in the early 1940s. Lands were transferred to the University with the understanding that they would be kept in their natural condition and used for scientific and educational purposes. Funds for acquisition of additional land, development of permanent buildings and preparation of accurate maps became available from a variety of sources including personal contributions, the National Science Foundation, the Max Fleischmann Foundation, the Minnesota Natural Resources Commission and the US Land and Water Conservation Program.

RESEARCH AND MANAGEMENT. Many research projects are carried out at Cedar Creek and hundreds of scientific manuscripts have been published. Use of radio telemetry for studying movements and activity of wild animals is of special significance. Currently underground movements of 16 pocket gophers with radio transmitters implanted in their bodies are being monitored by an automatic tracking system controlled by microprocessors and a microcomputer. The system is producing unique data which are being used to study spacing, reproductive behavior and effects of digging and feeding on native and introduced plants.

Techniques and equipment developed at Cedar Creek are now in world-wide use for research on seals in Antarctica, tigers in Nepal, lions in Africa, sea otters in Alaska, wild horses in Nevada and, of course, many species such as deer, fox, raccoon, ruffed grouse, horned owls and gray squirrels at Cedar Creek. Pioneering studies by Cedar Creek scientists on polar bears demonstrated the feasibility of tracking animals by satellite. Other important research in progress concerns social behavior in ducks, insect colonization on native plants and effects of fertilizer on succession and productivity of old-field ecosystems.

Land management includes a program of controlled burning to restore the prairie and oak savanna that prevailed for centuries in the natural landscape. Some areas that have been burned annually since 1964 now exhibit characteristics not seen in this region since settlement in the 1800s. In addition, a small tract of agricultural land is abandoned each year so that a series of different-aged sites is available for time-related ecological studies. Data are being used to study invasion, growth and decline of agricultural weeds and establishment of native prairie species.

APPLICATIONS. Results of Cedar Creek research are being utilized by many organizations, including the Minnesota Department of Natural Resources, Nature Conservancy, US Fish and Wildlife Service, and US Marine Mammal Commission. The following examples illustrate current applications. 1. Burning experiments on oak savanna at Cedar Creek aided the Nature Conservancy and the Department of Natural Resources in developing land management plans using controlled burning. 2. Data revealing that cattail marshes were the most productive ecosystems in Minnesota, even more productive than fertilized corn fields or aspen forests, provided the stimulus for current research on utilization of cattails for energy. 3. Radio-tracking data on movements of red foxes enabled biologists to model the spread of rabies in fox populations and design methods to control the disease.

SCOPE. Cedar Creek serves Minnesota broadly by providing research and teaching facilities for six colleges from the University, Biological Sciences, Agriculture, Forestry, Liberal Arts, Institute of Technology and Veterinary Medicine. It also serves other colleges and universities, both within and outside Minnesota, and has sponsored visiting scientists from abroad. A nature trail is maintained for public use, and classes from nearby high schools frequently visit on field trips.

SIGNIFICANCE. In this time of increasing concern for man's environment, it is important to recognize the value of past and future contributions of research facilities such as the Cedar Creek Natural History Area. Applications of research findings from Cedar Creek play an important role in sound management of our forests, farmlands, prairies, lakes, marshes and all natural resources.

J.R. Tester
Director

[Signature]
NATURALIST
Cedar Creek Natural History Area

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KNOWING THE DEDICATED PEOPLE who formed the Cedar Creek Area and the scientists who have presented its values has been a wonderful experience. It is fortunate that it could be saved for future Americans.