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Effects of the 1976 Seney National Wildlife Refuge Wildfire on Wildlife and Wildlife Habitats

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EFFECTS OF THE 1976 SENEY NATIONAL WILDLIFE REFUGE WILDFIRE ON WILDLIFE AND WILDLIFE HABITAT

Compiled by Stanley H. Anderson

Stanley Anderson, the principal investigator and project coordinator, compiled the material for this publication and supervised the bird and habitat field research. Daniel Coble, Wisconsin Cooperative Fishery Research Unit, provided the data on fisheries; Deanna Dawson, Patuxent Wildlife Research Center, analyzed the data and conducted the bird and habitat work; and Alfred Gardner, Denver Wildlife Research Center, designed and supervised the mammal research. David Grigal, University of Minnesota, and Ronald Nussbaum and Charles Olson, University of Michigan, conducted research on soils, amphibians and reptiles, and habitat mapping, respectively. James Selgeby, Great Lakes Fishery Laboratory, conducted the analysis of water quality, and Daniel Thompson, Editorial Office, assisted in the selection of study plots.

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Abstract

In the summer of 1976 a wildfire burned 260 km² on the Seney National Wildlife Refuge in Michigan's Upper Peninsula. The U.S. Fish and Wildlife Service evaluated the fire's impact on wildlife and wildlife habitat by sampling in burned and adjacent unburned areas from 1977 through 1979.

The fire burned in irregular patterns with varying degrees of intensity. In some burned areas dead trees or downed logs were the only vegetative remains, whereas other areas were difficult to recognize as burned areas after leaves covered the ground. Where the fire was severe, structural changes occurred in the habitat creating areas for species such as sharp-tailed grouse (*Pedioecetes phasianellus*), black-backed three-toed woodpeckers (*Picoides arcticus*), and black bear (*Ursus americanus*). The patchy nature of the fire caused the diversity of wildlife to increase on the Refuge. American woodcock (*Philohela minor*) and snipe (*Capella gallinago*), already common on the Refuge, became more abundant as edge habitat increased. White-tailed deer (*Odocoileus virginianus*) populations showed little change because of the lack of winter habitat. Studies in the third year after the fire indicated that young amphibians and reptiles were more common on the burned plots than on the unburned study sites.

Fish populations were similar in ponds and streams near burned and unburned regions. Significant differences were not found in the chemical composition of water and soils at burned or unburned sites.

The overall impact of the fire was to create a more diverse habitat by setting back succession in some areas. The results of the research provide some insights into the effect of fire on an ecosystem with a relatively short growing season. Implications are discussed for the use of fire as a management tool in these habitat types.

In the late afternoon of 30 July 1976, an isolated thunderstorm passed over the interior of Seney National Wildlife Refuge and ignited a small fire 5 km from the nearest road (Fig. 1). Two days later the fire was reported to the refuge manager by the Michigan Department of Natural Resources (DNR) Fire Patrol plane pilot. The manager was unable to locate the fire from the road so he attempted to find it on foot. Standing water, however, prevented entry into the area in which the fire was reported.

Following these attempts, the manager remained in contact with the DNR and requested the support of the regional Fish and Wildlife Service (FWS) aircraft. Several additional unsuccessful attempts were made to get into the area on foot. The FWS aircraft flew over the area on 3 August and located the fire in Section 1, T44N, R15W east of Walsh Ditch. It had grown from less than 0.5 ha when first reported to more than 80 ha.

By 10 August observers reported that the fire covered about 500 ha. At that time, a crew of refuge and State forest personnel moved into the bog wilderness area with bulldozers. Efforts to reach the fire were again unsuccessful because of standing water and thick humus. Even though there was standing water, the spring and summer of 1976 was unusually dry, contributing to the rapid spread of the fire.

On 10 August an observer from the Boise Inter-Agency Fire Center (BIFC) flew over the fire. The fire continued to expand, and on 16 August fire fighters estimated that about 700 ha were involved. At that time, people and equipment were sent from BIFC. On 17 August a fire boss coordinated the fire-fighting effort. Operations were concentrated on the construction of a fire line and road up the east side of Walsh Ditch.

On 22 August heavy winds and low relative humidity fostered erratic burns as the fire began to sweep both north and south. During the night the fire rapidly advanced southeast, crossed the south refuge boundary, and burned into State and private lands. On 24 August, 160 men with four pieces of heavy equipment attempted to contain the fire that now covered about 4,000 ha. Additional crews

Fig. 1. Fire perimeter and location where 1976 fire began (point 00) on Seney National Wildlife Refuge, Seney, Michigan. Paired habitat and bird plots are numbers 1–7; each plot had an 8-ha burned an 8-ha unburned study area.

Fig. 2. Aerial view of fire.

from BIFC arrived, but still the fire burned wildly and by 26 August covered 7,700 ha. On 28 August, backfires were established in containment attempts (Fig. 2).

The fire crew was partially successful in containing the fire on 29 August; however, high winds and low humidity continued to cause hot spots. By 6 September the fire covered 26,000 ha as backfires were completed, and on 7 September it was considered contained. The fire was declared controlled on 9 September and the BIFC returned part of their crew to Boise, leaving some personnel to put out burning embers.

On 12 September high gusty winds from the southeast plus low humidity again created extreme fire conditions. The smoldering hot spots within the burned perimeter broke into flames in many areas. Gusts of wind carried the fire north of the original fire line (Highway M–28), running 9 km on a front about 2 km wide. This new burn covered parts of the Grand Sable State Forest and adjoining private forest holdings. Additional men were brought in from the BIFC and the Forest Fire Division of DNR. By 16 September, more than 1,000 people were making a renewed effort to bring the fire under control. The fire was contained on 21 September and declared under control the following week. A total of 30,000 ha were burned, of which 22,800 were on the Seney Refuge, 6,500 on State forest, and 700 on private lands.

The fire, known as the Walsh Ditch Fire, covered over 260 km^2 of which nearly half was burned by backfires. More than 1,200 people fought the fire.

The FWS was greatly concerned about effects of the fire on habitat and wildlife. A special team of wildlife biologists was sent to the area to make a preliminary survey and to appraise the probable impact on fish and wildlife. On 12 October, the Deputy Associate Director (Research) of the Service established the Seney Fire Evaluation Team. Through his memo of that date, he directed the group (1) to evaluate the severity of the fire's impact on fish and wildlife habitat on the Refuge and, as appropriate, in surrounding areas; (2) to establish a sampling and monitoring design for follow-up study within the various habitat types; and (3) to prepare a report on the study group's findings with recommendations for additional research or monitoring efforts.

The team met at Seney National Wildlife Refuge Headquarters on 13 October 1976 for 10 days of extensive fieldwork including surveys of mammals and fish, studies of water chemistry, and photographic surveillance at selected plots (D. Q. Thompson, compiler. Preliminary evaluation of 1976 Seney wildfire. Unpublished report to U.S. Fish and Wildlife Service, 14 February 1977. Editorial Office, USFWS, Fort Collins, CO 80523). Results of these studies indicated there were no apparent short-term changes in water chemistry that would directly affect the Refuge's flora and fauna. Samples of fish populations adjacent to the burn, and from waters away from the burn, showed that populations were similar. Fire opened up areas, enabling many forms of wildlife such as deer, geese, and grouse to forage

on green shoots, seeds, and other materials that dropped or were blown into the area.

A number of recommendations were made by the team concerning future wildlife studies to evaluate the fire's impact. These recommendations were considered by the FWS, which established the Fire Evaluation Program in the spring of 1977. The objectives of the program were to study the impact of the fire on wildlife on the Refuge for 3 years. Specific objectives were to (1) document changes in vegetation types by use of aerial photos for each of 3 years; (2) establish permanent plots in burned and unburned locations in order to evaluate wildlife habitat; (3) establish permanent census plots for bird populations in the burned and unburned habitat; (4) continue sampling the small mammal census lines established in 1976; (5) establish new census plots in habitat not originally covered; (6) measure the quality and quantity of nutrients released into the surrounding lakes and streams each year to determine if the fire had adversely affected the soil nutrient level which in turn would have an impact on stream flora and fauna, as well as on the vegetation that would eventually grow in the soil; (7) prepare a vegetative cover map from the aerial photos and verify the extent of the fire with ground checks; (8) evaluate the effects of the fire on all wildlife living in the area; and (9) prepare a plan for continued evaluation after the initial study was completed.

Seney National Wildlife Refuge

The 38,631-ha Seney National Wildlife Refuge is in Schoolcraft County in the Upper Peninsula of Michigan. The Refuge lies in the southwest quadrant of the junction of State Highways 77 and 28 near the village of Seney. It extends westward from Highway M–77 and the towns of Seney and Germfask for about 26 km and south from Highway M–28 for about 21 km (Fig. 1).

Climate of the region is characterized by cool winters and summers with temperature extremes of $-44°$ to $+40°$C. The average annual precipitation is 70 cm, of which more than half falls as rain between April and September. Over 255 cm of snow generally falls during the winter months and settles into a snowpack of 75 cm or more.

The land consists of flat, wet, sandy mounds and ridges, mostly within marsh-like habitat. The soils form intricate patterns, resulting in mosaics of vegetation.

The entire area was inundated by a high water phase of the glacial Great Lakes, probably in the intermediate post-Algonquin time (Hough 1958, 1963). The Seney plain must have been reworked by shore processes during the post-Algonquin time, perhaps 9,500 to 10,000 years ago (Heinselman 1965). This large water deposition then resulted in the Strangmoor bogs and patterned organic terrain near the Seney area. The marshy water extended fingerlike projections in and around the wooded areas and where soils have been pushed together by glaciers. Trees and forests have developed on higher areas, and sand dunes probably became the sand knolls. The exact time when the area was inundated could have ranged anywhere from 4,000 to 9,400 years ago.

Fig. 3. Dense unburned spruce stand.

The vegetation on the Refuge is very diverse. On the basis of the Michigan Land Cover-Use Classification System (MLCUCS), the Refuge consists of broadleaf deciduous forests, generally quaking aspen (*Populus tremuloides*) mixed with paper birch (*Betula papyrifera*). Occasionally, plots of white pine (*Pinus strobus*), red pine (*Pinus resinosa*), and jack pine (*Pinus banksiana*) predominate. In some areas, dense woods of black spruce (*Picea mariana*) are found (Fig. 3). The vegetation appears similar to the northern taiga forest. Wooded wetlands, open lakes, and marshy grasslands are common. Foot travel is very difficult because of the many marshes and changes in vegetation.

In the southwestern portion of the Refuge, 10,178 ha are designated as a wilderness area. Within the wilderness area about 3,642 ha are set aside as the Strangmoor Bog Registered National Landmark. This is one of the rare patterned organic terrains found in the northern United States. Locally, it consists of the Seney, Creighton, and Driggs

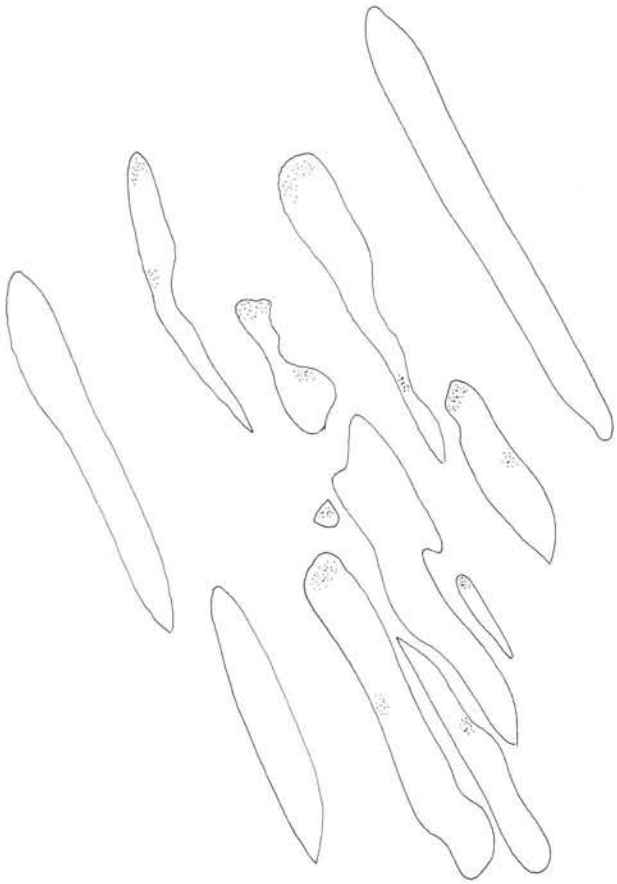

Fig. 4. Pattern of bog forests in wilderness area.

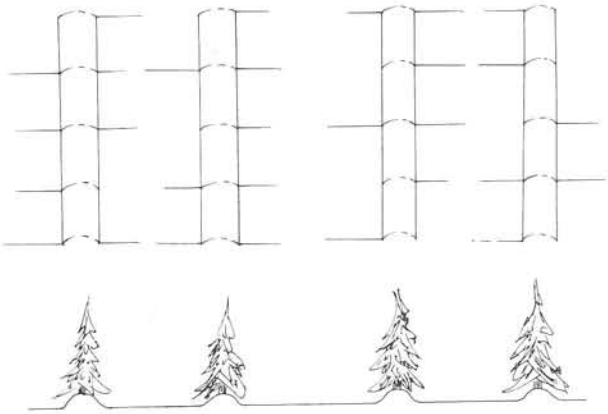

Fig. 5. Bog pattern showing ridges which often had tamarack and hollows.

marshes. In an ecological sense, the patterned terrain is not a marsh but a complex of bogs and fens. This whole region is a vast and nearly level sand plain, deposited from outwashes when the last ice sheet (Valders) receded. This plain lies 222 m above sea level and gently slopes S 15° E with a fall of 3 to 6 m/km. Since the glacial retreat, a continuous blanket of organic soil has accumulated in this shallow outwash valley. The peat blanket has now become a meter or more thick. In the intervening areas a thin, peaty veneer formed over the sand (Heinselman 1965), interrupted by sand knolls, which probably were sand dunes formed some time after the sand plains.

Long string-like bog forests consisting of tamarack (*Larix laricina*), black spruce, and red maple (*Acer rubrum*) exhibit a strong north–south orientation. These forests are generally 100 m wide and often more than 1 km long (Fig. 4). Between these forests are long, narrow strips of bog (Fig. 5). The bog consists of alternating low bog ridges which often have tamarack and wet, sedgey hollows which form cross-bandings that can be easily seen on aerial photos. The sand knolls support upland vegetation which is dominated by red and white pine. The ground cover consists of sedges, grasses, ferns, and low shrubs.

Downslope from the string bog and bog forest complex, the peatlands support a variety of vegetative cover. Intermittent sand knolls are surrounded by vast meadows which have very little resemblance to the tamarack forest and bog complex lying immediately to the north. The dominant vegetation in these meadows consists of sedge (*Carex* sp.) and cotton grass (*Eriophorum* sp.). On the sand knolls and ridges the soil is not fertile and can support only a few species of plants.

History of Land Use

The marshy Seney area has been left relatively untouched by human activities with the exception of some pine logging and a few deliberate fires (Ammann 1957). The organic soil overlying much of the lowland sand plain has stayed moderately fertile but has never been suitable for agriculture because of the high water table, short growing season, and frequent summer frosts. In some fields, man-made drainage ditches have lowered the water table in unsuccessful attempts to grow crops.

Beaver dams, which have changed the course of water and streams, have always been plentiful in the marshy areas, except in the more centrally located, highly patterned Strangmoor bogs.

From 1800 to 1940, much of the timber was logged around the Seney marshes. Destructive timber cutting, repeated fires, poorly planned drainage, and land clearing took a heavy toll on the vegetation. The original vegetation was destroyed and the peat, especially in accessible areas close to ditches and rivers, was burned. Even today, tire ruts made in the 1920's and 1930's are evident in the bog wilderness. The slow vegetative recovery is the result of the short frost-free season (15 June–27 August) which averages only 73 days.

Refuge History

On 10 December 1935, the Seney National Wildlife Refuge was officially established by presidential proclamation on the recommendation of the Michigan Conservation Department. The primary purpose was to provide resting and nesting areas for waterfowl. Extensive drainage changes and resulting lakes were made by the Civilian Conservation Corps during the late 1930's when they constructed many of the dikes and ditches on the Refuge. Twenty-one pools were made, ranging from 40 to over 400 ha and resulting in 2,800 ha of open water. The primary source of water for the Refuge pools was the Driggs River, which flows from north to south on the Refuge.

The Refuge currently provides food and rest areas for migrating waterfowl. A number of other management objectives are established within the Seney Refuge Master Plan. These include maintenance of open areas to attract white-tailed deer (*Odocoileus virginianus*), sharp-tailed grouse (*Pedioecetes phasianellus*), and American woodcock (*Philohela minor*); open season for fishing in some lakes; and nature trails for the many visitors that come to the Refuge each year.

Fire History in the Upper Peninsula

Fire is not new in the Upper Peninsula of Michigan. Jenkins (1943) traced the history of forest fires and their effects on wildlife from the lumbering era to the late 1930's. He pointed out that the ecological disturbances during this period were extensive and obscured most geological development that occurred in the area. Robson (1950:21) stated, ". . . from time immemorial but more especially since the beginning of act of settlement, about 1825, forest fires have occurred annually [in the Upper Peninsula of Michigan]."

In looking through field notes to try to determine the natural cover of the area, Jenkins (1943) found that almost every discussion made some mention of fire in the mixed forest–marsh areas. He noted that this was particularly true if the area was situated in any sizable area of Grayling sand. He went on to speculate that practically all the present jack pine areas have been burned over periodically. He suggested that about 250,000 ha in northern Michigan were desirable deer range for hundreds of years because of the effects of fire. Ancient fires that burned the jack pine were unhindered except by rain and natural barriers. The encroachment of most of those fires on swamps and surrounding deciduous forests probably assisted in maintaining suitable habitat for such species as ruffed grouse (*Bonasa umbellus*), eastern cottontail (*Sylvilagus floridanus*), deer, and bear.

D. Q. Thompson (unpublished report) investigated the frequency and distribution of lightning fires in the Seney bog. To determine the probability that lightning would strike and kindle a fire, he investigated fire reports in the Refuge files and found that lightning caused fires in 1954, 1964, 1967, and 1976. Thompson concluded that fires were not likely to occur annually but rather within each decade. All of the fires originated in remarkably similar locations. Thompson also showed that fire was correlated with periods of relatively low water levels. Miller (1977) showed that the severity of the 1976 drought predictably caused difficulty in controlling the Seney Wildfire.

Fire and Wildlife—A Review

In the early to middle 20th century, foresters and plant ecologists believed that fires should be controlled. These feelings resulted from the massive control efforts that were undertaken after the destructive fires of the late 19th century. Some of those fires burned large areas of the forest in the north-central region and destroyed entire towns, occasionally killing hundreds of people. Wildlife biologists observed that changes occurred in wildlife communities when forests formerly subjected to periodic fires were not burned for decades. Timber grew tall but crowns grew closer together, resulting in the gradual suppression and sometimes elimination of food plants. Many areas lost some traditional or desirable species. An example in Michigan is the changes in game bird habitat distribution. Greater prairie chicken (*Tympanuchus cupido*) habitat gradually became sharp-tailed grouse country; sharp-tailed grouse country eventually turned into ruffed grouse habitat; and ruffed grouse habitat became too dense for the birds and the hunters (Smith 1947).

By the 1950's, continued evaluation of the effects of fire on wildlife showed that fire appeared to increase wildlife species diversity through increased habitat diversity. The diversity of northern ecosystems, including those of the Upper Peninsula of Michigan, was maintained in part by fire (Ahlgren and Ahlgren 1960; Scotter 1972; Wright and Heinselman 1973; Alexander and Dube 1982; Heinselman 1982). Smith and Henderson (1972) also expressed this viewpoint in a review of the use of fire in Canadian forests and presented good supportive evidence for the expanded use of fire to manage wildlife. Some species (e.g., Kirtland's warbler, *Dendroica kirtlandii*) required burned-over habitat. Fire was suggested as a tool in managing ecosystems for wildlife in many parts of the United States (Tester and Marshall 1963; Kilgore 1973; Loope and Gruell 1973; Rowe and Scotter 1973; Chen et al. 1975).

By the 1960's a great volume of literature appeared on fires and wildlife (Cushwa 1968; Bendell 1974). Studies showed that a number of bird species benefited from fire in jack pine (Pinkowski 1977). Niemi (1978) documented breeding bird population changes in an area in northern Minnesota that had been burned in a manner similar to the Seney area. He reported a drop in the number of species in the controlled burned area. Ammann (1957) discussed major habitat changes that had occurred in Schoolcraft County near Seney Refuge in a 35- to 40-year period. These major changes were reflected in wildlife populations. Reductions in the total number of white-tailed deer, prairie

chickens, and sharp-tailed grouse were accounted for by the lack of periodic fires.

Alexander and Dube (1982) believed that fire must be considered as a factor in maintaining wildlife and wildlife habitat in northern circumpolar locations. The diversity of biological entities, as well as diversity of biological processes, can be maintained only by including fire which alters the habitat structure and sets back plant succession.

Methods

Extensive fieldwork began on Seney National Wildlife Refuge in spring 1977 to answer the questions posed in the Fire Evaluation Program.

Vegetation Analysis

Seven pairs of 8-ha (400- × 200-m) study plots were established in burned and unburned habitats characteristic of the region (Fig. 1). Five of the paired plots were in forest and two were in bog. The habitat on each pair of plots was judged to have been similar before the fire (Table 1). We sampled vegetation at 10 random points in each 8-ha plot using a modified James and Shugart (1970) technique. All trees ≥ 8 cm dbh within a 0.04-ha circle were recorded by species and dbh size class. Stem counts of shrubs in three height classes were made in subplots along the southern radius of the circle. Saplings and shrubs > 150 cm in height were counted by species within a 1- × 10-m strip, shrubs 50 to 150 cm were recorded on half the width of the strip, and shrubs < 50 cm were inventoried within a 1-m^2 subplot at the center of each circle. Percentage ground cover by life form and average height of vegetation were also estimated on the 1-m^2 plot. Life forms considered included seedlings, shrubs, grasses and sedges, forbs, bracken fern (*Pteridium aquilinum*), other ferns, and cryptophytes.

Other variables measured included average height of trees in the 0.04-ha circle, average distance from the top of the canopy to the base (canopy depth), and percentage canopy cover (Fig. 6). Vegetation was measured in each of the circular samples in late July or August during the 3 years after the fire. Yearly data from each plot were summarized and expanded to estimates per hectare. Vegetation also was sampled at 11 points in burned and unburned marsh, and on sand islands. Changes in growth and structure of vegetation were also recorded on infrared and black-and-white photographs taken annually at each sample point.

Map Preparation

Colar-infrared (CIR) aerial photos were taken of the burned area with Kodak Aerochrome 2443 infrared film (nominal scale of 1:15,840); altitude of the aircraft was between 2,400 and 2,700 m. The photographs were taken on

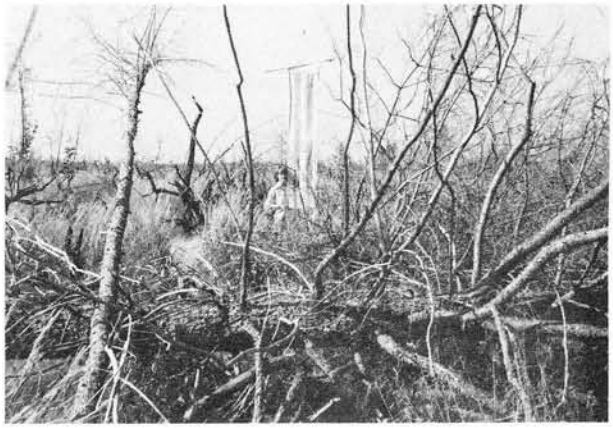

Fig. 6. Backdrop used in collecting habitat data. Observer determined vegetation layering by interpreting the number of squares covered.

18 September 1976 immediately after the fire, on 11 May 1977 in the spring following the fire but before the green vegetation appeared, on 3 October 1977 when all the green vegetaton was up, on 2 October 1978, and on 22 September 1979. It was possible to distinguish details of trees, ground cover, and most water bodies including rivers and creeks. These photos showed the severity of the burn and the vegetation and its recovery, and provided the basis for preparing a post-fire vegetation map of the Refuge.

The post-fire vegetation cover was mapped directly onto U.S. Geological Survey (USGS) 7.5-minute quadrangle sheets at a scale of 1:24,000. Cover-type changes and the actual fire perimeter were mapped as an overlay to this base map. Work was performed by contract with the University of Michigan (L. J. Sugarbaker, unpublished data).

The MLCUCS (1976), a four-level expansion of the land-use classification scheme prepared by Anderson et al. (1976) for USGS, was used. Where vegetation cover types could not be classified beyond the second or third level, zeros were added to provide consistent four-digit classification codes.

The smallest area that could be consistently classified and identified on a 1:24,000 map sheet was about 1 ha (MLCUCS 1976). The presence of sand knolls as an integral part of the patterned bogs and their effect on quality of wildlife habitat made their identification and mapping important for this study. Thus, those areas < 1 ha were identified by point symbols which indicated whether or not they supported overstory vegetation.

The CIR aerial photography obtained by the FWS on 11 May 1977 was the primary source for mapping post-fire vegetative cover. CIR photography obtained on 18 September 1976 and 3 October 1977 was also used as supporting information.

Mapping criteria for severity of burn and vegetation recovery were based on spectral signatures of major cover

types as well as the association of types. Most of the burn area consisted of grassland and shrubland associations that appeared uniformly dark on the 11 May 1977 satellite image. It was difficult to assign any burn severity ratings to these areas, but the degree of burn on associated sand islands was used as an indicator of the severity of burn on adjacent areas.

LANDSAT imagery taken during and after the fire provided an additional remote sensing data set for evaluating the effects of the fire. LANDSAT imagery was acquired for several dates including 3 June 1976 (pre-fire), 23 August 1976 (fire), 10 September 1976 (fire), 11 May 1977 (post-fire and same date as CIR photography), and 9 August 1977. Imagery was acquired for bands 5 and 7 (0.6–0.7 μm and 0.8–1.1 μm, respectively) in 18.5-cm film positive format for all five scenes. The entire burn and Refuge area occupied only a small portion of the scene, and a 5.2- by 5.2-cm section was cut out of each film positive and placed in an I^2S color additive viewer. When projected into the I^2S viewer, the image from 18.5-cm film positives was at a scale of 1:150,000. We prepared small scale maps of the burned area and major vegetation changes from the LANDSAT bands 5 and 7 composite scenes using the I^2S viewer. The information from manual interpretation of the LANDSAT imagery was then compared with the fire boundary and vegetation maps were prepared from the color-infrared aerial photography.

Mammals

Twenty-four traplines, modified from the system used by Calhoun (1949), were established during the study. All lines were permanently marked with metal fence posts. Each line consisted of 20 stations arranged in a straight line with 15 intervals between stations. Three snap traps (one rat trap and two museum specials) were set at the most likely capture site within a 1.5-m radius of each station. Each trap was baited with a mixture of peanut butter and rolled oats.

During the original survey (October 1976), eight Calhoun lines were established. Fifteen more were added during 1977, and 1 was added in 1978 for a total of 24. All lines were not trapped each year because of high water in some areas. Surveys of small mammal populations were made in the spring and fall of 1977, and in spring of 1978, 1979, and 1980. The mammal study sites were in areas similar to or near the habitat plots. Additional lines were placed in areas where mammal populations were thought to be particularly sensitive to fire conditions, such as marshes or in distinctive habitats such as the birch–beech woodland in the southeastern part of the Refuge.

Observations and indirect signs such as footprints and scat were recorded for other mammals including deer, black bear (*Ursus americanus*), beaver (*Castor canadensis*), striped skunk (*Mephitis mephitis*), and raccoon (*Procyon lotor*).

Birds

Bird populations were censused on the 14 habitat plots (Fig. 1) during the three breeding seasons following the fire. The territory mapping method (International Bird Census Committee 1970) was used. Each plot was visited from seven to nine mornings between 0530–1000 from late May through June. On each visit, the location of each bird heard or seen was plotted on a map as the observer traversed the study plot. The number of territorial males was determined from a composite of maps from all visits during the breeding season. Additional counts were made in habitats that were too small to accommodate sampling plots. Eleven points were established in the manner of Ferry and Frochot (1970). The species and number of birds heard or seen from the marked point and within the habitat type were recorded on four 10-min visits. The maximum number of individuals detected was used as an index to the number of territorial males present in each habitat.

Reptiles and Amphibians

Amphibian and reptile data were gathered by a University of Michigan group under contract with the FWS (R. A. Nussbaum and P. Rosen, unpublished data). In 1979, 3 years after the fire, seven sites were intensively sampled to determine which species of amphibians and reptiles were present in the habitats.

Two pairs (burned–unburned) of plots were censused for more detailed data in areas rich in species. Paired comparisons were made between the burned and unburned plots. All individuals in the census were identified, sexed, measured, and then released. Notes were taken on the breeding condition of the mature individuals. Observational data were collected on time of egg-laying and number of egg masses for ambystomatid salamanders. Amphibians and reptiles were sampled on the Refuge 8–18 May, 8–27 July, and 16–25 September 1979.

Each plot was censused with a wire screen drift fence (30 m × 76 cm high). The fence had six pitfall traps set along each side and funnel traps at the end. Six minnow traps were set to capture aquatic salamanders wherever aquatic habitat occurred adjacent to a drift fence. In similar habitat, aquatic turtle traps (one per site) were installed for 1 week during the July sample period.

Dry upland areas were also censused on five pairs (unburned–burned) of plots on either side of the Driggs River and North Dike Road. These plots were sampled by recording observations of all animals active on the surface and by searching under all surface objects and inside all stumps and logs.

Fish

During the initial survey conducted in the fall of 1976 and in the spring of 1979, the fish population was sampled at three sites in pools and three in streams. The purpose was to determine the immediate impact of the fire on fish and to establish sample designs for future studies. A pool not open to fishing, but located near Refuge headquarters, was selected as a control. A second sample site, Marsh Creek Pool, the largest pool on the Refuge, was also closed to fishing. Fire burned extensively around and down to the edge of Marsh Creek Pool. At the third pool sample (C_3), which was open to fishing, the fire burned only around the western portion. Marsh Creek, which ran through the middle of the burned area, was the major tributary of both pools in the burned area.

Walsh Creek, north of Highway M–28, served as a control. An experimental burned section was selected immediately south of the highway where the fire had burned on both sides of the stream. Marsh Creek was also sampled immediately south of M–28.

Fish sampling efforts consisted of one overnight set of multifilament nylon gill nets. The gill net was set in borrow pits parallel to the dike. In streams, a portable DC stream shocker was used for 4.7, 13.9, and 15.0 min in both the control and experimental sections.

Water Quality

Water was sampled in October 1976, and again in the spring of 1978. From maps, aerial photos, and ground inspections, investigators chose to sample the following five bodies of water within the burned area: (1) C_3, an impoundment of about 325 ha when at full pool; (2) Marsh Creek Pool, an impoundment of about 470 ha at full pool; (3) Marsh Creek, a small stream, with very little flow, running about 30 km through the burned area; (4) Creighton River, a small stream with moderate flow traveling about 6 km through the burned area; and (5) Walsh Creek ditch complex, a small stream–ditch complex with moderate flow running about 20 km through the burned area.

Eleven sampling stations were established at the five water bodies. Attempts were made to select stations that would yield information at points upstream and downstream from the burned perimeter. All samples were collected between 1130 and 1330 and immediately processed at Refuge headquarters. Duplicate 1-L samples were drawn at the 11 stations. Conductivity, alkalinity, and pH were determined from raw water subsamples. Subsamples of raw water were retained to determine chloride and sulphate levels. Additional subsamples of raw water were preserved with nitric acid to later determine sodium, potassium, calcium, and magnesium levels. Portions of raw water and water filtered through glass fiber filters were frozen to later determine phosphate and nitrate levels.

Soils

University of Minnesota investigators assisted in this project by conducting soil analyses in 1979 (D. F. Grigal, unpublished data). The purpose was to characterize chemical and microbiological properties of the soil. Samples were taken from six pairs (burned–unburned) of habitat plots (Creighton North, Driggs, Spruce, and Walsh, all on mineral soils), and fen and fen–forest on organic soils. The sites were selected to represent a range of vegetation types and topographic features that conformed to vegetation sampling areas.

Three soil pits were dug on each of the mineral soil sites (four pairs or eight sites). Soil profiles were described by using standard procedures and samples were collected from each of the major horizons. At three locations near each pit the forest floor was divided into 0–1 and 0–2 horizons and sampled quantitatively within a 115-cm^2 area. At each of the organic sites, the soils were described and sampled at two locations but soil samples were not collected at the forest sites.

In mid-July, investigators began to study the fire's effect on decomposers. Sampling was restricted to mineral soil sites. At each site a 100- × 100-m grid (1 ha) was laid out. At three of the pairs of sites, 10 locations on the grid were randomly chosen for placement of litter bags to study soil decomposers. At the remaining pair of sites (spruce), litter bags were placed in such subunit of the grid.

Nylon litter bags, 7.5 × 10 cm, were constructed of 2-mm nylon mesh. In each bag, investigators placed three 2.5-cm-diameter leaf discs (total area 19.6 cm^2) and inserted the bags between the 0–2 and 0–1 soil horizons. Every 2 weeks they withdrew one bag and collected a soil sample from the 0–2 to A-1 interface for microbiological analysis. This sampling continued for 8 weeks.

After a bag was removed, the remains of the discs were cleaned and pressed. The amount of decomposition was measured by passing the disc through a Hayashi Denko, Type AAN-5 Automatic Area Meter. Areas were accurate to 0.01 $cm.^2$

Soil samples collected from the pits dug in each plot (separated into A-1, A-2, and B horizons) were analyzed for pH in 0.01 M $CaCl_2$ (Peech 1965) by using a soil:solution ratio of 1:1 (weight:volume). The method of Yuan (1959) was used for determining amounts of changeable hydrogen and aluminum. Changeable bases were analyzed with an inductively-coupled plasma spectrometer on solution extracts obtained by leaching 3-g soil samples with 30 mL of 1-N MH_4OAc (Chapman 1965). Available phosphorus was analyzed colorimetrically on extracts obtained with Bray's No. 1 solution (Olsen and Dean 1965). The micro-Kjeldahl technique of Bremner and Tabatabai (1972) was used to analyze the nitrogen content of the samples. Organic matter in the samples was determined by a colorimetric method (DeBolt 1974). Two-way analyses of variance, testing site (vegetation plot), and treatment (burned versus unburned), were used to analyze the resulting data.

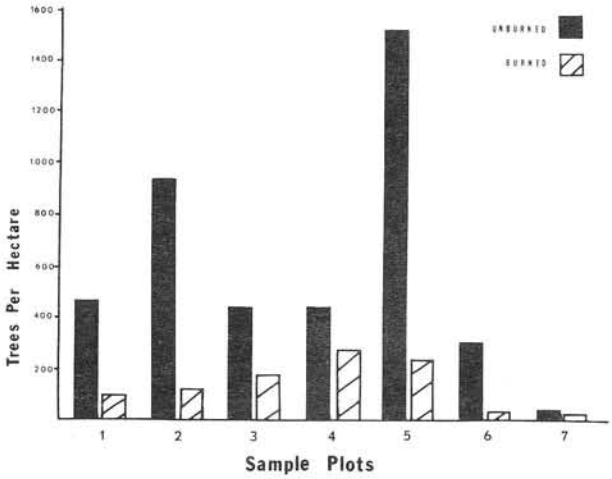

Fig. 7. Trees per hectare on burned and unburned sample plots.

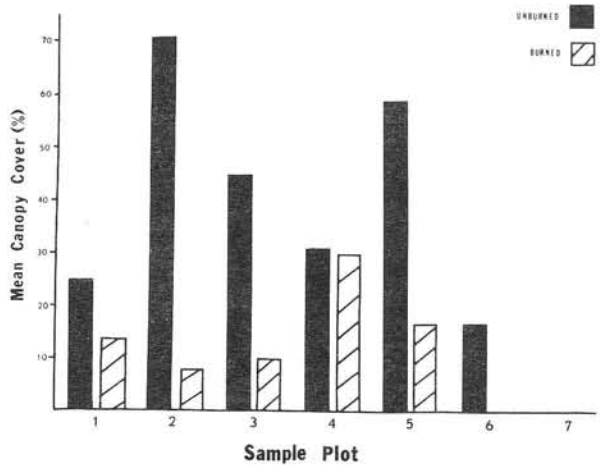

Fig. 8. Percent canopy cover on burned and unburned sample plots.

Results

Post-fire Vegetation

Within its perimeter, the fire burned patchily and with varying degrees of intensity. Early estimates indicated that as much as 35% of the area was untouched by the fire (J. R. Frye, personal communication). Moreover, some areas experienced only a light surface burn with little vegetation destroyed. In other areas, upper organic layers were ashed and all herbaceous and woody vegetation was consumed.

Although fire destroys forests, it also stimulates the growth of many plant species. Some herbs and shrubs, most notably blueberry (*Vaccinium* spp.), show increased flowering and fruiting following fire. Tree reproduction is encouraged by reduced competition for nutrients, moisture, heat, and light, by creation of suitable seedbeds, release of seeds from cones, and release of minerals essential for plant growth.

The most obvious effect of fire is the change in structure and species composition of forest communities. Measured differences between burned plots and the corresponding unburned plots should be interpreted cautiously because baseline data are not available for this study. Differences in structure and composition cannot necessarily be attributed to the fire. The number of trees and canopy cover on the unburned plots were greater than in burned plots (Figs. 7 and 8). The effects of the fire could be seen on the burn plots which generally had more snags (Fig. 9), more ground cover (Fig. 10), denser shrubs (Fig. 11), and denser seedlings (Fig. 12).

Post-fire vegetation response varied greatly with the severity of the burn and the habitat type (Table 1). In areas which experienced only a light surface burn, the effects of the fire were scarcely apparent after the second growing season (1978). For example, on most of study plot 4B, fire

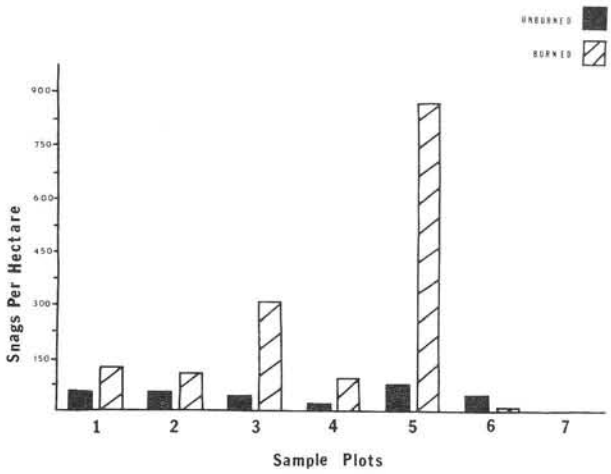

Fig. 9. Snags per hectare on burned and unburned sample plots.

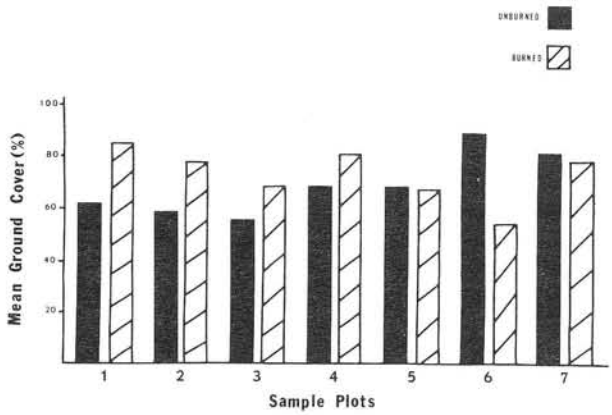

Fig. 10. Percent ground cover on burned and unburned sample plots.

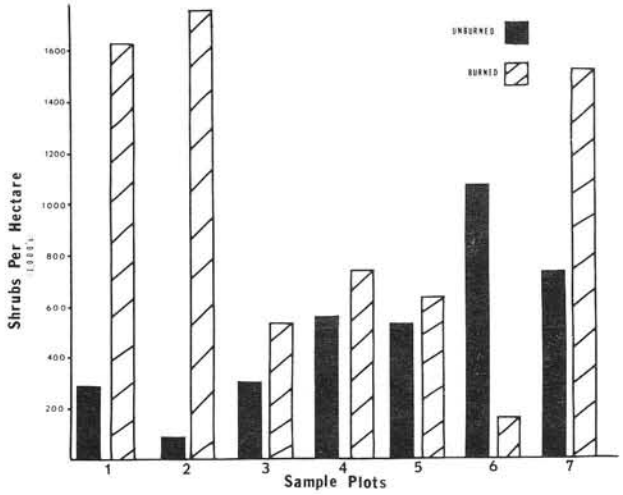

Fig. 11. Shrubs per hectare on burned and unburned sample plots.

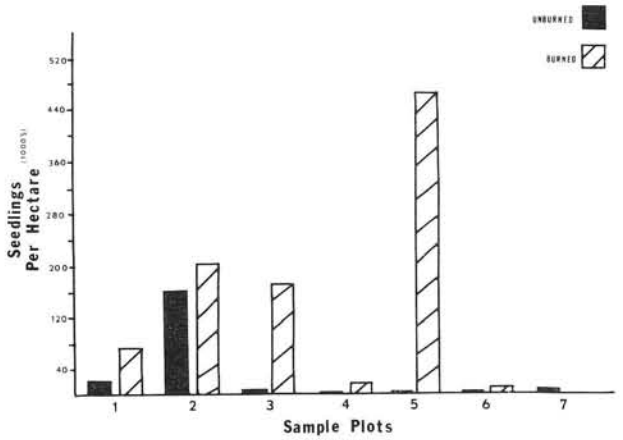

Fig. 12. Seedlings per hectare on burned and unburned sample plots.

scars on the trunks of live pines and high production of blueberries were the only signs of a recent fire. On areas where the burn was severe, forests have been set back to a much earlier stage of succession. Large areas of study plots 3B and 5B, devoid of vegetation in 1977, were being colonized by mosses (*Dicranum* sp., *Polytrichum* sp.) and liverworts.

Balsam fir (*Abies balsamea*), a dominant species on unburned mixed forest plots (1, 2), was absent from burned plots. Aspen increased in dominance on burned plots, indicating the adaptability of this species to fire. Besides the turnover in dominant species evident in the remaining live trees on all study plots, the growth of burned forests was influenced further by the more open canopy and removal of understory vegetation. With the reduction in competition, aspen suckers and seedlings reached densities of thousands per hectare by 1978. By 1979, the growth of jack pine

Table 1. *Habitat type and burn characteristics of study plots on Seney National Wildlife Refuge, Seney, Michigan. Habitat on each pair of plots was judged to have been similar before the 1976 fire.*

		Burned plots	
Paired plots	Forest type	Percent of plot burned	Severity of burn[a]
1	Mixed forest (*Populus* spp.–*Picea* spp.–*Acer rubrum*)–alder (*Alnus* spp.)	100	Moderate
2	Mixed forest	100	Moderate
3	Pine (*Pinus resinosa*–*P. banksiana*)	90	Moderate–Severe
4	Pine	95	Light
5	Spruce (*Picea mariana*)	90	Severe
6	Bog (*Larix laricina*–*Acer rubrum*)	100	Severe
7	Bog (*Betula pumila*–*Chamaedaphne calyculata*–*Andromeda glaucophylla;* no trees present)	100	Moderate

[a]Light – primary surface burn; Moderate – scarring of trees, a few dead trees; Severe – trees all dead, complete burn.

seedlings had increased, particularly on plots 3B and 5B. These species will probably dominate burned areas until the water table returns to normal levels, thereby making site conditions intolerable, or until conditions become suitable for shade-tolerant species such as balsam fir and black spruce.

Except for blueberry, stimulated growth of shrub species was not apparent in 1979. Several lowland shrubs, i.e., speckled alder (*Alnus rugosa*), bog birch (*Betula pumila*), winterberry (*Ilex verticillata*), and mountain holly (*Nemopanthus macronata*), were absent or uncommon on burned plots, probably because of the high intensity of fire on areas with an accumulation of organic material (e.g., peat). On such areas, the impact was most severe close to fire's origin.

Study plot 6 exemplified the effect. In the unburned bog forest, beneath the tamarack–red maple overstory, a lush growth of royal fern (*Osmunda regalis*) interspersed with winterberry, mountain holly, and speckled alder created the appearance of a tropical forest. Plant species in the unburned fen were characteristic of northern bogs; leatherleaf (*Chamaedaphne calyculata*), bog rosemary (*Andromeda glaucophylla*), and bog birch were the dominant shrubs. Very little remained of the forest on the burned plot. Trees were killed and only a few snags left standing as fire destroyed the root systems when it burned through the peat (Fig. 13).

In the summer after the fire, almost no live vegetation

Fig. 13. Burned bog forest, August 1977.

Fig. 14. Burned bog and sand islands, August 1977.

was present on burned areas; organic material had been reduced to a red ash (Fig. 14). In the spring of 1978, cotton grass had colonized the burn and by late summer of that year the area had been covered by many grass species. A few shrub species, such as bog birch and willow (*Salix* spp.), were becoming reestablished by late summer of 1979, but it was obvious that recovery of fen–forest communities would be very slow.

Use of Aerial Photography to Monitor Habitat Change

The CIR aerial photography proved very useful in documenting vegetation recovery. Major changes in vegetation were discernible in comparing the aerial photographs taken in October 1977, 1978, and 1979. The two burned plots near the Creighton truck trail appeared black immediately after the fire. Many black mounds of sand were still visible in the spring following the fire. By the fall of 1977 some grasses had begun to grow and showed a characteristically pink coloration. By the fall of 1978, a number of areas were covered with grass along Creighton Road where the burn had been hot. There were more dead trees the second year because some were still green the first year after the fire. By 1979, most of the area blackened by the fire contained low shrubs and grasses.

Aerial photos also showed changes in the predominantly spruce plots found along Walsh Farm Road. In the spring of 1977, dense black areas appeared on the west side of the road where backfires were started. Only snags were found on ground checks of this area immediately following the fire. In the fall of 1977, very little vegetation was apparent. In 1978 dead trees showed readily on the aerial photos and few grasses were apparent. In 1979 it was possible to see the increased number of shrubs and grasses. The burned site was compared each year with the unburned area east of Walsh Farm Road where dense tree cover remained virtually unchanged.

One of the best comparisons of CIR aerial photos involved a bog–fen area. The topographic orientation of the Strangmoor bogs could be seen easily on the aerial photos. The black area representing the large burn was readily apparent in May 1977. The unburned regions where trees were not growing showed up conspicuously white, whereas forested strips appeared pinkish in color. Little change had occurred by the fall of 1977. By 1978 grass species were scattered in the burned open humus. The burned bog forests appeared similar to previous years on the aerial photos. The unburned area was clearly distinguished; however, on the photos, white was encroaching in many of the burned bogs, indicating that it would not be long until grasses covered the ground. By 1979 the burned bog forest was still distinguished as a blackened area. The downed trees could still be identified on the photos. The open bog and marsh were much less apparent. Much of this area had been covered with dense growths of grass and, although it was possible to discern slight outlines of the burn, it was only with

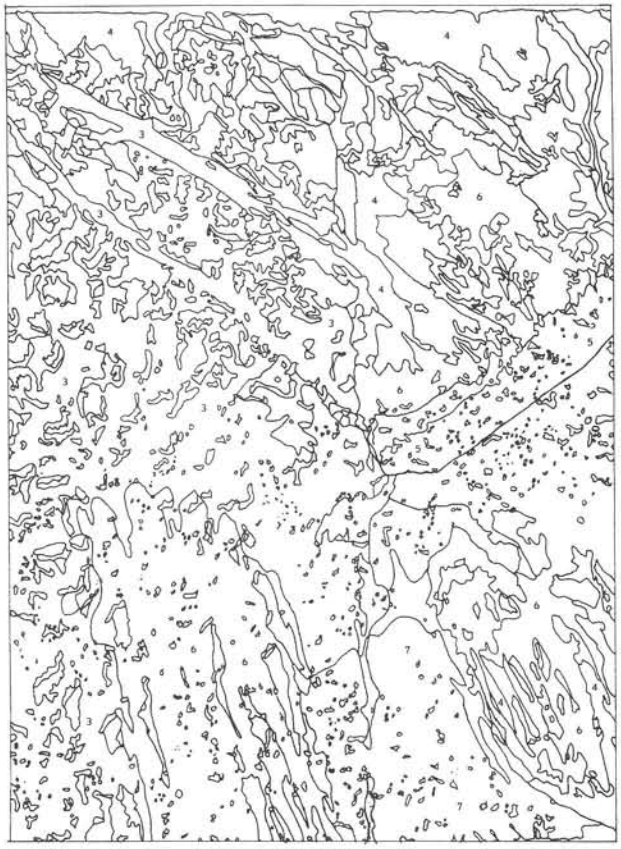

Fig. 15. Portions of post-fire vegetation cover map of Seney National Wildlife Refuge: 3 = rangeland; 4 = forest; 5 = C_3 pond; 6 = wetlands; 7 = barren.

ground truth knowledge that the boundaries were clear to the observer.

Habitat Map of Seney National Wildlife Refuge

Pre-fire Vegetative Cover

Pre-fire vegetation was determined in approximately the same manner as post-fire cover. The primary source for documenting pre-fire vegetative cover was USGS black-and-white aerial mapping photography from May 1971; however, it was often easier to determine pre-fire vegetation boundaries from the CIR post-fire photography. Burned-over forest, for example, could usually be seen as either standing or windblown snags, and burned shrublands produced a different texture than burned grasslands. It was possible to document changes in cover types by overlaying a manuscript copy of the pre-fire map onto the post-fire cover map. These changes were recorded on a new overlay.

Post-fire Map

A post-fire vegetative cover map (Fig. 15) was prepared and compared with pre-fire vegetation to determine changes that occurred as a result of the fire. It could be argued that, because pre-fire and post-fire maps were available, vegetation changes and successional trends could be interpreted from the two maps. However, all areas were mapped according to the dominant vegetation type present at the time the imagery was obtained. In most lowland grasslands, for example, the encroachment of alder and willow shrubs seemed inevitable, but the invasion of shrubs was at least temporarily set back where fire passed through these areas. Both the pre-fire and post-fire maps indicated that this entire area was dominated by grasses, but the appearance of these grasslands was considerably changed. A second example occurred on the burned uplands and sand knolls. In most instances, surface fires burned through these areas leaving more than half of the overstory intact (usually dominated by red pine). Both pre-fire and post-fire maps indicated that upland conifers were the dominant vegetation type.

For all examples previously given, except black spruce, the intensity of burn was relatively light. Areas that experienced a hot burn (all available fuel nearly consumed and mineral soil left exposed) were in a transitional state. The MLCUCS called for mapping such barren ground as transitional. In some of these areas, however, seedbed conditions were favorable, and regeneration, particularly aspen, was quickly established. At the time of mapping, the dominant vegetation was aspen. The probability that aspen will survive in these areas is low, and it seems more appropriate to label this habitat as transitional. Surely all areas are dynamic and the point at which one recognizes something as being temporarily static, in terms of its map classification, is arbitrary.

Interpretation of the 11 May 1977 LANDSAT image alone did not give good results in mapping severity of burn but comparative interpretation of the May and August imagery was more successful. The most severely burned areas were closely associated with the slow vegetation recovery areas mapped from the August image (Fig. 16). Comparison of the two images also permitted mapping of areas where extensive post-fire mortality occurred (Lachowski and Anderson 1979).

Interpretation of the combined images from bands 5 and 7 of LANDSAT scenes dated 11 May 1977 and 9 August 1977 was completed with the aid of an I^2S color additive viewer. Mapping the fire boundary from the 11 May 1977 imagery proved to be accurate for all areas burned with the exception of the light surface fire which produced little or no effect on the overstory forest canopy. In such areas, post-fire mortality was minimal and the burn could not be detected beneath the forest canopy.

Attempts were made to interpret the relative severity of burn and then compare severity ratings with vegetation recovery interpreted from the 9 August 1977 LANDSAT image. Some relationship seemed apparent between the severity of burn index mapped in Fig. 16 and the amount of vegetation recovery mapped in Fig. 17, particularly in the

Fig. 16. Interpretation of LANDSAT scene (11 May 1977) for degree of burn on a relative scale (0 indicates a complete burn and 4 a light burn).

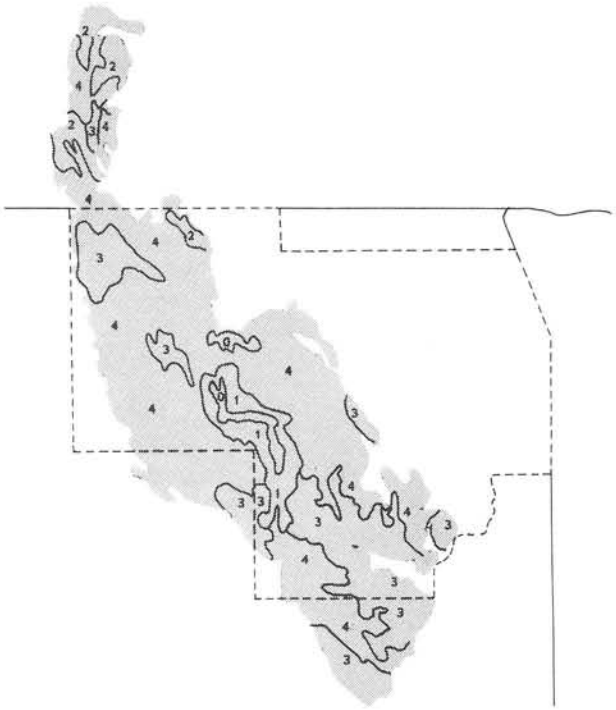

Fig. 17. Interpretation of LANDSAT scene (9 August 1977) for relative vegetation recovery zones combined with burn boundary information (0's indicate areas where no vegetation recovery could be detected and 4's indicate sufficient recovery to make delineation from unburned areas difficult).

Walsh Ditch area (center of Refuge) where the severest burns occurred and vegetation recovery had been very slow.

Mammals

Mammal trapping during October 1976 showed an immediate adverse effect on small mammals. Seventy-four percent of all animals captured were caught on unburned areas. The masked shrew (*Sorex cinereus*), by far the most abundant species, was the only small mammal found in *Carex* marsh habitat (Table 2).

A conspicuous feature of the marsh habitat immediately following the fire was the system of relatively narrow and slightly elevated ridges of vegetation traversing these areas. These ridges were deer trails, which before the fire were narrow, troughlike depressions kept wet by the cutting action of hooves into the peaty substrate. Because these wetter trails were better able to withstand the fire, they remained as raised strips.

Overwinter survival of small mammals was poor in 1976–77 (Table 2). Although the total number of traplines had been increased from 8 to 21 in the spring of 1977, only 11 animals were caught in the burned areas, whereas the unburned sites had 71 animals. These low numbers may be the result of normal early spring mortality in this region. Flooding of bog, fen, and marsh habitats during snowmelt would force most small mammals to move to better-drained sites. Hard freezes during the period of snowmelt would also exact a toll. The combined lack of cover, inadequate food, and increased vulnerability to predation could further reduce population numbers on the burned areas.

By October 1977 there had been a marked recovery from the population low observed in the spring. This recovery occurred despite widespread flooding in many of the lower-lying regions, particularly the *Carex*-dominated marshes. The numbers of mammals were significantly higher (Fig. 18) on transects in burned habitats (X^2, $P < 0.05$; based on comparable sets of transects in burned and unburned habitats).

Meadow vole and the southern red-backed vole were the most common small mammals in October 1977. The high numbers (130 specimens = 27% of total catch) and the higher relative frequency (present on 13 of 22 traplines) in the fall of 1977 as compared with any other trapping period (e.g., 30 trapped in 1980 when present on 7 of 24 lines) indicated a population peak for red-backed voles. The meadow vole population was also high (30% of total catch) in October 1977. The results indicated a shift from numerical

Table 2. *Mammals captured or observed on Seney National Wildlife Refuge, Seney, Michigan, fall 1976–fall 1980.*

	Trapping Period											
	Fall 1976		Spring 1977		Fall 1977		Fall 1978		Fall 1979		Fall 1980	
Species[a]	B[b]	U	B	U	B	U	B	U	B	U	B	U
Arctic shrew (*Sorex arcticus*)	1	15		2	2	8	15	20	20	8	55	41
Masked shrew (*Sorex cinereus*)	24	66		16	34	42	93	84	42	72	102	147
Water shrew (*Sorex palustris*)		1									6	5
Pygmy shrew (*Microsorex hoyi*)		1					1	2	1	4		1
Short-tailed shrew (*Blarina brevicauda*)		5				5	24	37	3	26		9
Starr-nosed mole (*Condylura cristata*)	1									1	1	
Eastern cottontail (*Sylvilagus floridanus*)	Ob		Ob									
Snowshoe hare, (*Lepus americanus*)		Ob		1		Ob		2		1	1	
Eastern chipmunk (*Tamias striatus*)				1				Ob		Ob		2
Least chipmunk (*Eutamias minimus*)		3	4	18	5	12	31	14	9	6	51	28
Woodchuck (*Marmota monax*)				Ob				Ob		Ob		Ob
Grey squirrel (*Sciurus carolinensis*)		Ob		Ob		Ob		Ob		Ob		Ob
Red squirrel (*Tamiasciurus hudsonicus*)		1		1		1			1	1		
Northern flying squirrel (*Glaucomys sabrinus*)	2	2				2	1	1	1	4	1	4
Beaver (*Castor canadensis*)	Ob	Ob	Ob	Ob	Ob	Ob	Ob	Ob	Ob	Ob	Ob	Ob
Deer mouse (*Peromyscus maniculatus*)	6	4	2	2	53	42	50	49	23	31	8	101
Southern red-backed vole (*Clethrionomys gapperi*)	5	2		9	36	94	24	43	8	43	5	25
Meadow vole (*Microtus pennsylvanicus*)		18	3	16	68	73	118	101	16	40	51	65
Muskrat (*Ondatra zibethicus*)	Ob		Ob		Ob	Ob	Ob	Ob	Ob		Ob	
Meadow jumping mouse (*Zapus hudsonius*)			5	2			6	3			26	33
Woodland jumping mouse (*Napaeozapus insignis*)								2				5
Coyote (*Canis latrans*)	Ob		Ob		Ob		Ob		Ob		Ob	
Red fox (*Vulpes vulpes*)		Ob		Ob		Ob	Ob	Ob	Ob	Ob	Ob	Ob
Black bear (*Ursus americanus*)	S		S		Ob		Ob		S		S	
Raccoon (*Procyon lotor*)		Ob		Ob		Ob		Ob		Ob		Ob
Least weasel (*Mustela nivalis*)										1		
Long-tailed weasel (*Mustela frenata*)						Ob						
Mink (*Mustela vison*)		Ob		Ob		Ob		Ob		Ob		Ob
Striped skunk (*Mephitis mephitis*)		Ob		Ob		Ob		Ob		Ob		Ob
River otter (*Lutra canadensis*)	Ob		Ob		Ob		Ob		Ob		Ob	
White-tailed deer (*Odocoileus virginianus*)	Ob	Ob	Ob	Ob	Ob	Ob	Ob	Ob	Ob	Ob	Ob	Ob
Number of trap nights	(8)		(14)		(10)		(13)		(12)		(16)	

[a]Scientific terminology according to Jones et al. (1979).
[b]B = burned; U = unburned; Ob = observed; S = sign of animal.

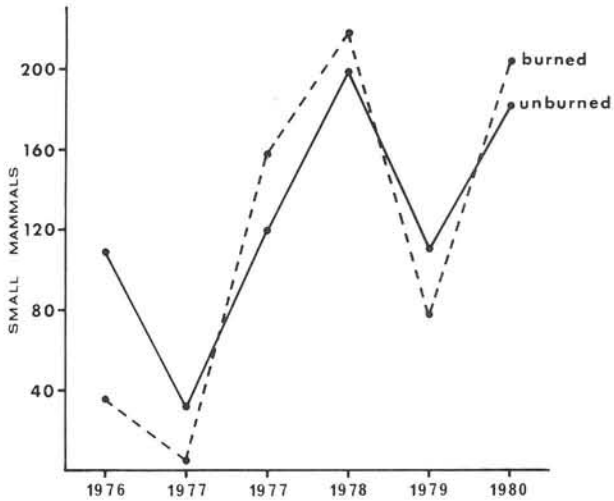

Fig. 18. Comparison of total numbers of small mammals caught on burned and unburned transects from 1976 to 1980. Differences between captures on burned and unburned transects were significant in the fall of 1976 (X^2, $P < 0.05$), spring of 1977 (X^2, $P < 0.005$), fall of 1977 (X^2, $P < 0.05$), and fall of 1979 (X^2, $P < 0.025$).

dominance by shrews in 1976 to dominance by mice and voles in fall 1977.

Populations continued to increase through 1978. Captures on all burned transects totaled 326 in September 1978 compared with 191 in October 1977. There were 359 specimens trapped on unburned transects versus 286 in 1977. There was no significant difference in capture success between 7 pairs of burned and unburned habitats ($X^2 = 0.957$) in October 1978.

In 1978 the southern red-backed vole population declined markedly, although mice and voles were still more common than insectivores. The relative numbers of masked shrew increased (25% of catch in 1978 versus 16% in October 1977). Populations of meadow voles were proportionately as high as in 1977 (30% of catch), and also numerically the highest encountered during the study (219). There was a shift from dominance by meadow voles in burned habitats in 1977 to dominance in unburned areas in 1978. A peak in the short-tailed shrew population was another feature evidenced by the 1978 survey transects.

Populations were lower in 1979 than in 1978 (Table 2). Insectivores were more abundant than small rodents. The numbers of mammals trapped on the unburned pairs of transects were significantly higher (X^2, $P < 0.025$) than those caught on burned transects. Meadow voles declined from about 30% of the total catch in fall of 1977 and 1978 to 15% in 1979. The short-tailed shrew population declined in frequency (present on 9 of 24 transects), but was still high (8.0%) when compared with fall of 1977 (1.1% of total catch).

The 1980 survey was accomplished in August to assess the relative importance of meadow jumping mice in the Refuge's fauna. These animals had been hibernating during the previous surveys. Although not as low as during October 1976, the water level was lower than during any of the preceding 3 years. As in 1978, there was no significant difference ($X^2 = 1.25$) between burned and unburned transects in 1980.

Numbers of mammals trapped in 1980 were higher than previous periods. It was possible that small mammal density was higher in 1978 because jumping mice made up 8.2% of the catch in August 1980, but only 0.3% in September 1978. Trapping at different periods in the season could influence the results because of time of hibernation and time of birth.

Insectivores were the most abundant group of small mammals caught during the 1980 survey. More arctic shrews (96) and masked shrews (249) were caught than at any other time. Arctic shrews made up 12.3% of the catch and were found on 17 of the 24 transects, in contrast with the 1977, 1978, and 1979 seasons when they constituted 2.1% (5 of 22 lines), 4.9% (13 of 21 lines), and 7.7% (11 of 24 lines), respectively.

The adverse impact of the fire on small mammals was of relatively short duration. By August 1980, all but the most severely burned "peat flats" in the wilderness area supported a diverse mammalian fauna, although there were still differences in species composition between burned and unburned plots (Figs. 19 and 20).

Populations of meadow vole, southern red-backed vole, short-tailed shrew, masked shrew, and arctic shrew showed Refuge-wide increases or peaks at different times during the study. With the exception of the southern red-backed vole, which was most abundant in the fall of 1977, relative densities of these species were highest on burned habitats the year before their populations peaked on unburned plots.

Quantified surveys were not made of the furbearers and larger mammals on the Refuge. A review of field notes revealed no evidence of serious impact by the fire on these larger mammals. Sightings of coyotes suggested that populations were high in 1978 and 1979, but were low in 1980 when none were seen. Red foxes, raccoons, skunks, least and long-tailed weasels, and river otters were seen or their sign noted on all surveys. Mink, muskrat, beaver, and snowshoe hares were also common and no influence by the fire was noticed on their populations. Deer were commonly seen during each year of the study and they probably benefited from the greater availability of browse as burned vegetation regenerated. Winter deer yards have not existed on the Refuge in recent history. The deer population was not adversely affected.

Black bears were seen or their sign noted on all surveys, but they first appeared commonly in 1979 and were definitely abundant in August 1980 when 28 sightings were recorded. The greater abundance of raspberries, blackberries, and blueberries on burned areas of the Refuge may

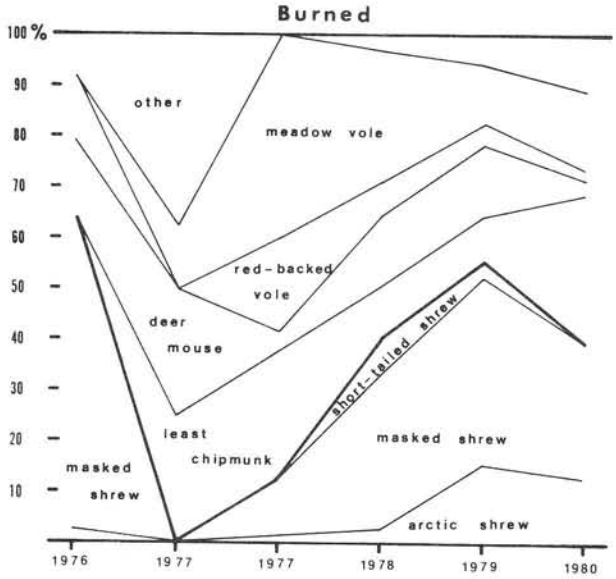

Fig. 19. Percentage composition of the seven most common small mammals recorded from transects on burned areas from 1976 to 1980. Proportions were determined from the total catch for each year. Number of transects summed for each year were 1976, 4; spring 1977, 7; 1978, 6; 1979, 7; and 1980, 7. Heavier line separates insectivores (below) from rodents (above).

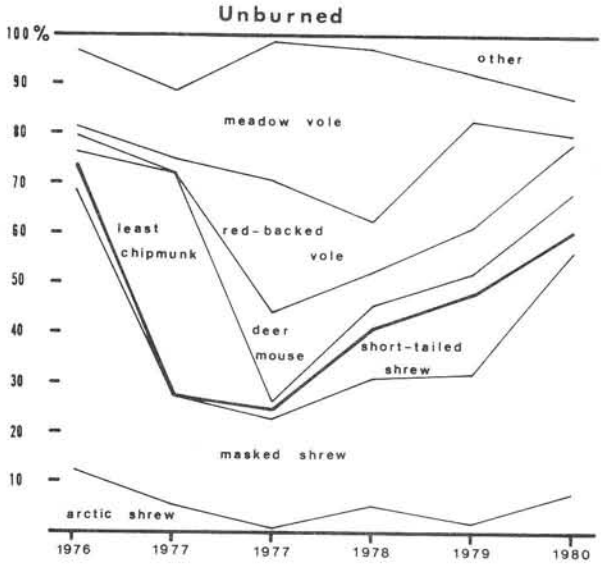

Fig. 20. Percentage composition of the seven most common small mammals recorded from transects on unburned areas from 1976 to 1980. Proportions were determined from the total catch for each year. Number of transects summed for each year were 1976, 4; spring 1977, 7; 1978, 6; 1979, 7; and 1980, 7. Heavier line separates insectivores (below) from rodents (above).

have contributed to increased numbers of bears. This supposition is supported by the observation that most bears were young, probably under 3 years old. Bears were a nuisance during most of the surveys, especially in 1980, because they frequently disturbed traplines.

Birds

We summarized the data from the 14 plots and indicated the prime habitat type and occurrence of bird species we heard or observed on the Refuge (Table 3). We used the diversity indices to investigate the effect of post-fire changes at the community level. Species richness and diversity were generally lower on burned study plots than on their unburned counterparts throughout the study (Fig. 21). Significant differences ($P \leq 0.1$) in bird species diversity were detected only on study plots where vegetative structure was radically changed by the burn. For example, nearly all trees were downed and shrubs were destroyed on the burned fen–forest plot (6B). Only 4 breeding species were observed in 1977, compared with 16 on the corresponding unburned plot. Additional species nested on the burned plot in the following years (six in 1978, seven in 1979) as a dense grass–sedge cover became established. The difference in diversity, though significant in all years, was greatest in 1977 (1.347 on the burned versus 2.528 on the unburned; $P < 0.01$).

Changes in the avian communities were better characterized by indices based on similarity of species composition and relative abundances. Bray–Curtis indices of similarity (Huhta 1979) were calculated on all comparisons of burned versus unburned study plots and on within-plot annual changes in communities (Table 4). In all circumstances, similarity between avian communities on burned and unburned plots was lower than that similarity on each study plot in consecutive years. Differences between burned and unburned plots were explained in part by a shift in the proportions of the avian community in different foraging guilds. On all pairs of plots, the burned plot had a higher proportion of bird species that typically forage on the ground or in the shrub layer than the corresponding unburned plot, and a lower proportion of species that typically forage in trees (Fig. 22). When considered in terms of the species involved, the replacement of forest interior species (e.g., golden-crowned kinglet, Cape May warbler, ovenbird) by edge and shrub species (e.g., common yellowthroat, white-throated sparrow, song sparrow) was apparent.

The magnitude of this shift was masked somewhat because patches of vegetation were missed by the fire on each burned plot. However, over the 3 years, many bird species were recorded as breeders only on burned plots. These included killdeer, common snipe, black-backed three-toed woodpecker, brown creeper, winter wren, northern oriole, Brewer's blackbird, and savannah sparrow. These species utilized the snags, brush, or open ground that resulted from the fire. Species recorded only on unburned plots included American woodcock, veery, golden-crowned kinglet,

Table 3. *Birds found on Seney National Wildlife Refuge, 1977–80.*

Species[a]	Scientific Name	Occurrence[b]	Habitat[c]
Broad-winged hawk	*Buteo platypterus*	U	MF,B
Spruce grouse	*Canachites canadensis*	U	C
Ruffed grouse	*Bonasa umbellus*	C	MF,B
Sharp-tailed grouse	*Pedioecetes phasianellus*	U	B
Sandhill crane	*Grus canadensis*	C	B
Killdeer	*Charadrius vociferus*	VC	B
American woodcock	*Philohela minor*	VC	MF
Common snipe	*Capella gallinago*	C	MF,B
Black-billed cuckoo	*Coccyzus erythropthalmus*	U	MF
Ruby-throated hummingbird	*Archilochus colubris*	C	MF
Common flicker	*Colaptes auratus*	U	MF
Yellow-bellied sapsucker	*Sphyrapicus varius*	C	MF
Hairy woodpecker	*Dendrocopos villosus*	C	MF
Black-backed three-toed woodpecker	*Picoides arcticus*	R	MF,C
Eastern kingbird	*Tyrannus tyrannus*	VC	MF,B
Great crested flycatcher	*Myiarchus crinitus*	O	MF
Alder flycatcher	*Empidonax alnorum*	C	MF
Least flycatcher	*Empidonax minimus*	C	MF
Eastern wood pewee	*Contopus virens*	C	MF,C
Tree swallow	*Iridoprocne bicolor*	R	MF
Blue jay	*Cyanocitta cristata*	C	MF
Common crow	*Corvus brachyrhynchos*	C	MF,C
Black-capped chickadee	*Parus atricapillus*	C	MF,C
Boreal chickadee	*Parus hudsonicus*	R	C
Red-breasted nuthatch	*Sitta canadensis*	U	C
Brown creeper	*Certhia familiaris*	C	MF,C
Winter wren	*Troglodytes troglodytes*	U	C
Short-billed marsh wren	*Cistothorus platensis*	U	MF,B
Brown thrasher	*Toxostoma rufum*	U	MF
American robin	*Turdus migratorius*	C	MF
Hermit thrush	*Catharus guttatus*	C	MF,C
Veery	*Catharus fuscescens*	C	MF,C
Golden-crowned kinglet	*Regulus satrapa*	C	C
Ruby-crowned kinglet	*Regulus calendula*	U	MF,C
Cedar waxwing	*Bombycilla cedrorum*	C	MF
Starling	*Sturnus vulgaris*	R	MF
Solitary vireo	*Vireo solitarius*	U	MF,C
Red-eyed vireo	*Vireo olivaceus*	R	MF
Black-and-white warbler	*Mniotilta varia*	C	MF
Golden-winged warbler	*Vermivora chrysoptera*	R	MF
Nashville warbler	*Vermivora ruficapilla*	R	MF,C
Magnolia warbler	*Dendroica magnolia*	C	C
Cape May warbler	*Dendroica tigrina*	C	C
Yellow-rumped warbler	*Dendroica coronata*	R	MF
Black-throated green warbler	*Dendroica virens*	C	MF,C
Blackburnian warbler	*Dendroica fusca*	U	C
Chestnut-sided warbler	*Dendroica pensylvanica*	C	MF
Pine warbler	*Dendroica pinus*	C	C
Ovenbird	*Seiurus aurocapillus*	C	MF
Common yellowthroat	*Geothlypis trichas*	C	MF
Mourning warbler	*Oporornis philadelphia*	R	MF
Canada warbler	*Wilsonia canadensis*	C	MF
American redstart	*Setophaga ruticilla*	C	MF
Bobolink	*Dolichonyx oryzivorus*	O	B
Red-winged blackbird	*Agelaius phoeniceus*	O	B
Brewer's blackbird	*Euphagus cyanocephalus*	U	MF
Common grackle	*Quiscalus quiscula*	O	MF
Brown-headed cowbird	*Molothrus ater*	R	MF
Northern oriole	*Icterus galbula*	C	MF

Table 3. *Continued.*

Species[a]	Scientific name	Occurrence[b]	Habitat[c]
Scarlet tanager	*Piranga olivacea*	O	MF
Rose-breasted grosbeak	*Pheuticus ludovicianus*	C	MF,C
Indigo bunting	*Passerina cyanea*	O	MF
Evening grosbeak	*Hesperiphona vespertina*	O	MF,C
Purple finch	*Carpodacus purpureus*	C	MF,C
American goldfinch	*Carduelis tristis*	O	MF,B
Savannah sparrow	*Passerculus sandwichensis*	C	MF,B
Le Conte's sparrow	*Passerherbulus caudacutus*	R	B
Vesper sparrow	*Pooecetes gramineus*	C	B
Dark-eyed junco	*Junco hyemalis*	C	MF,B
Chipping sparrow	*Spizella passerina*	VC	MF,B
White-throated sparrow	*Zonotrichia albicollis*	VC	MF,B
Lincoln's sparrow	*Melospiza lincolnii*	O	B
Swamp sparrow	*Melospiza georgiana*	O	B
Song sparrow	*Melospiza melodia*	C	MF,B

[a]Scientific and common names follow American Ornithologists' Union (1957) and supplements.
[b]VC – very common; C – common; O – occasional; R – rare; U – uncommon.
[c]MF – mixed forest; C – coniferous forest; B – bog, grassland.

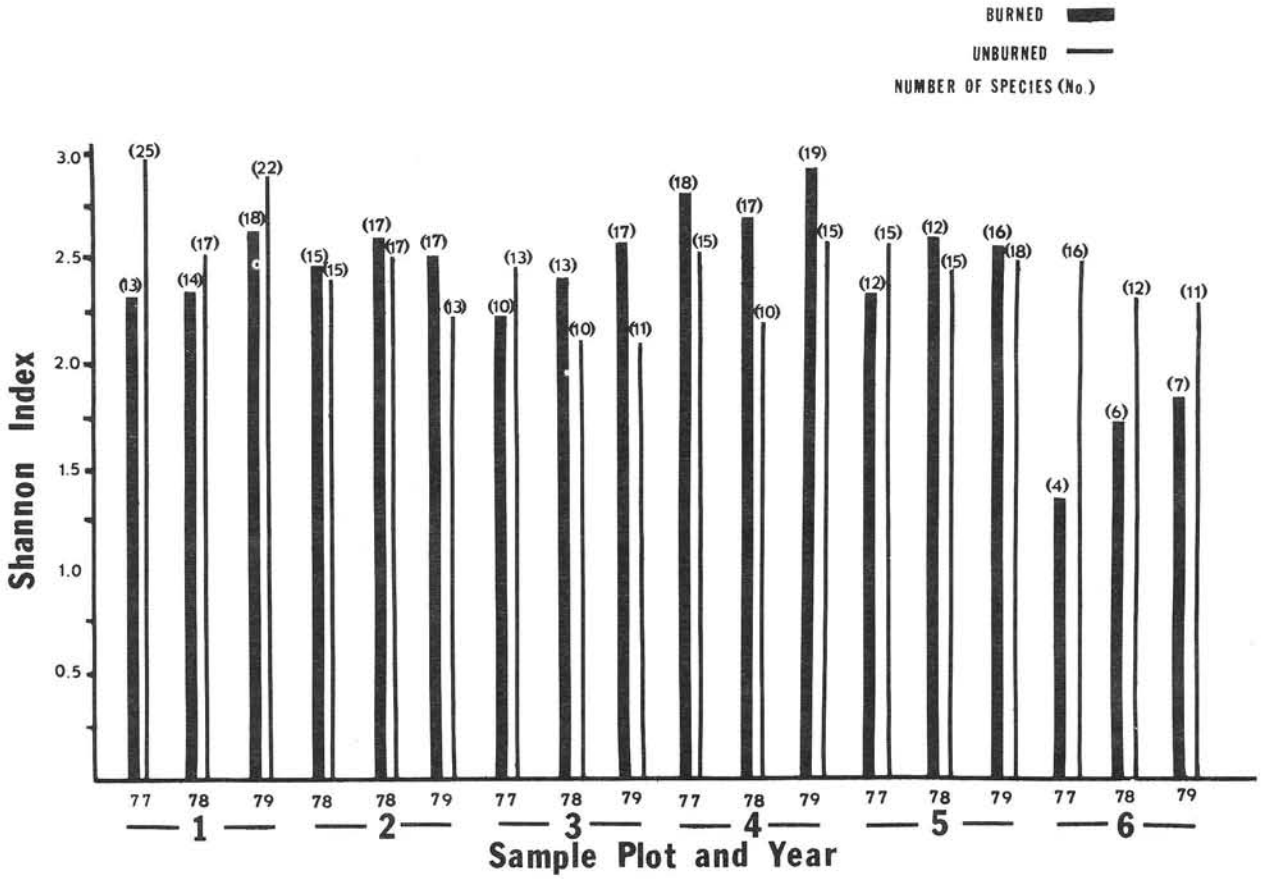

Fig. 21. Bird species diversity on sample plots 1977, 1978, and 1979.

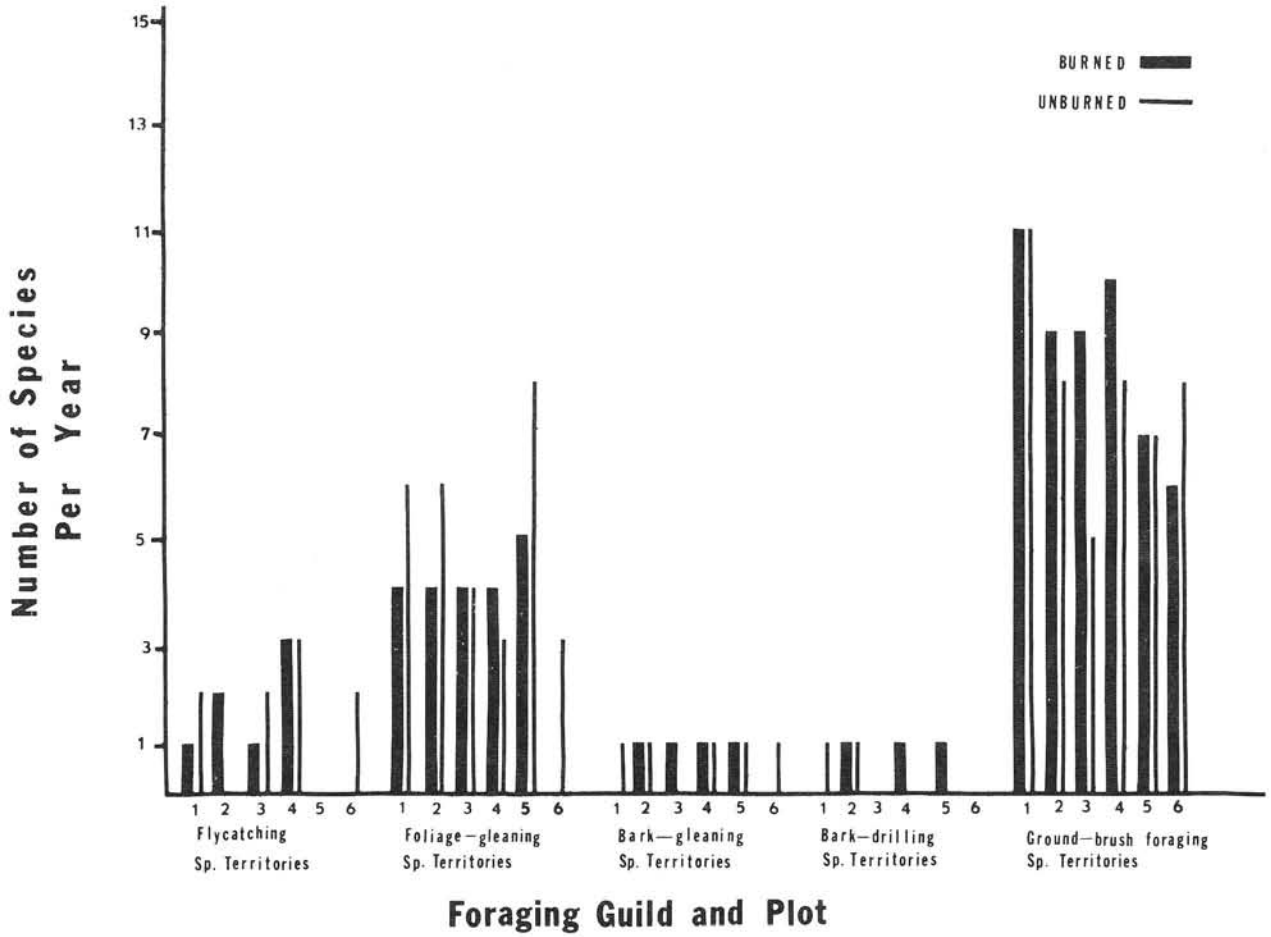

Fig. 22. Bird foraging guilds on plots 1–6.

golden-winged warbler, American redstart, indigo bunting, and LeConte's sparrow. Several other species, breeding on unburned plots, were recorded on burned plots only in patches of trees missed by the fire. These included boreal chickadee, ruby-crowned kinglet, Cape May warbler, Blackburnian warbler, and ovenbird.

Annual changes in avian communities were more difficult to assess. An observer would expect similarity in the communities of undisturbed habitat to be high in consecutive years (barring drastic weather changes or other extreme influences), and similarity of disturbed habitat undergoing more rapid successional changes to be lower. Examination of the Bray–Curtis indices (Table 4) confirmed the expected. Between-year Bray–Curtis indices were lower on burned study plots than on the corresponding unburned plots. Exceptions were study plot 4 (Fig. 1), a red pine–jack pine forest on which the vegetation was changed little by a light surface burn, and plot 7, a mixed bog forest.

The number of nesting species increased on most burned plots from 1977 to 1979 (Fig. 23). However, a pattern was not apparent when 1977 and 1979 results were compared on each plot by using similarity indices (Table 4). The similarity of bird communities was much lower in comparisons between burned plots where stimulated seedling and sprout growth had greatly increased stem density in the shrub layer (plots 3B, 5B). This lower similarity indicated a fluctuation of species composition and abundance with the development of additional habitat. These plots showed an increase in species that nest or forage in the shrub layer. However, the 1977 versus 1979 similarity of communities on some unburned plots (2U, 4U, 5U, 6U) was also lower than that between consecutive years. The time interval of the study was probably too short to observe all changes in avian communities as a result of post-fire succession. Differences in observers and weather may also have prevented a clearer pattern from emerging.

Reptiles and Amphibians

Twelve species of amphibians and eight reptile species were recorded on Seney Refuge (Table 5), including the

Table 4. *Similarities between bird communities on Seney National Wildlife Refuge as evidenced by Bray–Curtis indices, 1977–79.*

	Plot						
	Mixed forest		Pine		Spruce	Bog	
Comparison[a]	1	2	3	4	5	6	7
U-1977 vs. U-1978	0.8061	0.7502	0.7252	0.6511	0.7367	0.7506	0.5101
U-1978 vs. U-1979	0.7432	0.7458	0.7581	0.6332	0.7631	0.8452	0.6284
U-1977 vs. U-1979	0.7831	0.7021	0.7252	0.5457	0.6777	0.7024	0.4627
B-1977 vs. B-1978	0.6412	0.6491	0.6355	0.7765	0.6788	0.7439	0.7325
B-1978 vs. B-1979	0.7018	0.6458	0.7107	0.6248	0.6323	0.7068	0.7998
B-1977 vs. B-1979	0.5571	0.6995	0.5413	0.6500	0.4454	0.6497	0.5846
B-1977 vs. U-1977	0.4138	0.4407	0.5454	0.5734	0.5553	0.2357	0.6834
B-1978 vs. U-1978	0.4626	0.3287	0.5133	0.5808	0.5684	0.2771	0.5739
B-1979 vs. U-1979	0.5353	0.3563	0.5553	0.5630	0.5295	0.3689	0.4831

[a]B – burned; U – unburned.

brown snake and grey treefrog, previously unknown on the Upper Peninsula of Michigan. The ring-necked snake (*Diadophis punctatus*), bullfrog (*Rana catesbeiana*), and four-toed salamander (*Hemidactylium scutatum*) were expected, when judged according to known habitat preferences and known geographic ranges (Conant 1975), but were not found on the Refuge despite special efforts to find them in the most likely habitats. The pickerel frog (*Rana palustris*), found throughout the Upper Peninsula, was not observed on the Refuge; this species usually occurs at low densities in Michigan, thereby making discovery difficult. Five other species, the milk snake (*Lampropeltis*

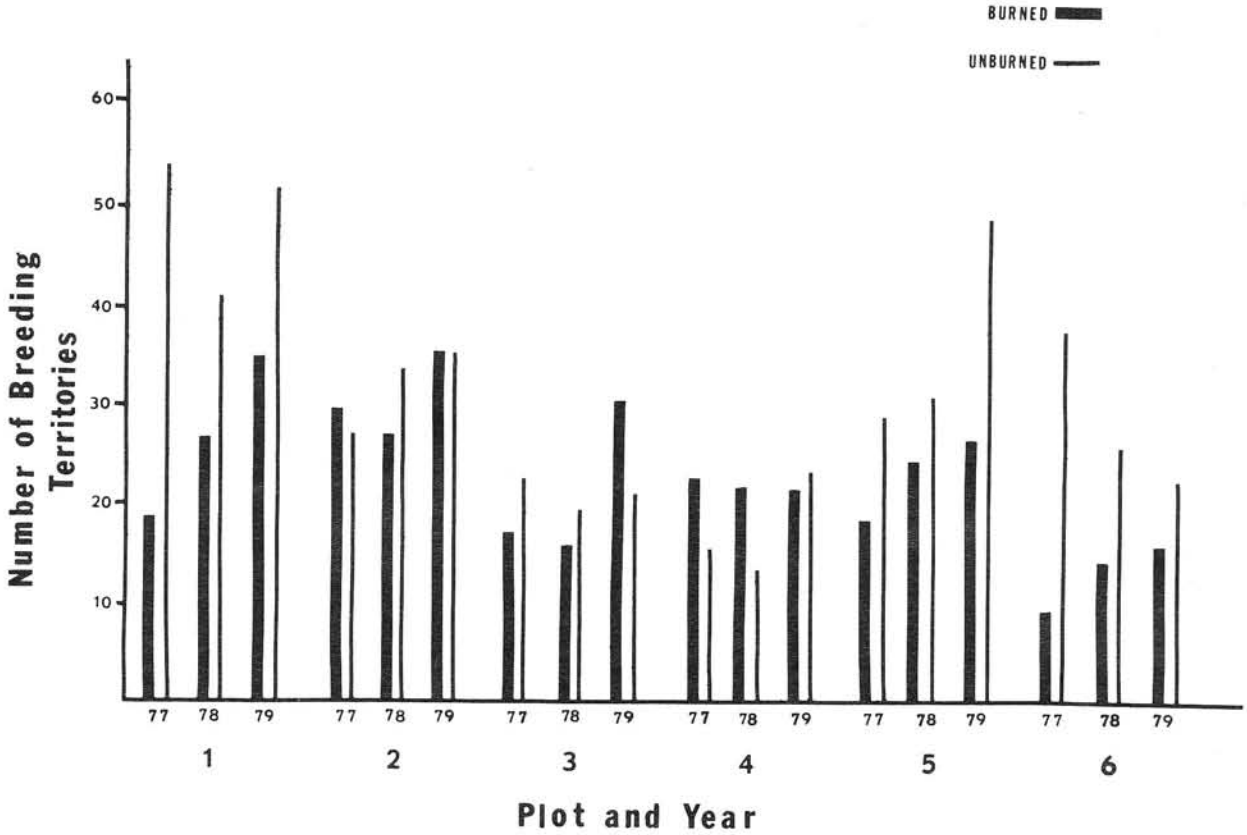

Fig. 23. Number of breeding bird territories on sample plots 1–6.

Table 5. *Amphibians and reptiles observed on Seney National Wildlife Refuge, Seney, Michigan, 1977–80.*

Species	Habitats[a]					
	Upland forest	Swamp	Shallow marsh	Deep marsh	River bottom	Deciduous forest
Turtles						
Wood turtle (*Clemmys insculpta*)	X				X	
Painted turtle (*Chrysemys picta*)			UC	X		
Snapping turtle (*Chelydra serpentina*)			UC	X		
Snakes						
Water snake (*Nerodia sipedon*)			X	X		
Brown snake (*Storeria dekayi*)		X				
Red-bellied snake (*Storeria occipitomaculata*)	X				UC	
Common garter snake (*Thamnophis sirtalis*)	X	X	X		X	X
Smooth green snake (*Opheodrys vernalis*)	X	UC				
Frogs						
Mink frog (*Rana septentrionalis*)			X	X		
Green frog (*Rana clamitans*)			X	X		
Leopard frog (*Rana pipiens*)		X	X			
Wood frog (*Rana sylvatica*)		X			X	
American toad (*Bufo americanus*)	X	X				X
Spring peeper (*Hyla crucifer*)		X				
Grey treefrog (*Hyla versicolor*)	X					
Grey treefrog (*Hyla chrysosoelis*)	X					
Salamanders						
Spotted salamander (*Ambystoma maculatum*)	UC				X	X
Blue-spotted salamander (*Ambystoma laterale*)	UC				X	X
Red-backed salamander (*Plethodon cinereus*)	X	X			X	X
Red-spotted newt (*Notophthalmus viridescens*)	UC		X		X	X

[a]X – common occurrence; UC – uncommon.

triangulum), fox snake (*Elaphe vulpina*), five-lined skink (*Eumeces fasciatus*), Blanding's turtle (*Emydoidea blandingi*), and tiger salamander (*Ambystoma tigrinum*), not previously known in the Upper Peninsula, were found peripheral to the Seney Refuge but not on the Refuge.

During the three survey periods, 1,918 frogs, 140 snakes, 80 salamanders, and 60 turtles were captured. About 200 turtles were observed basking. Frogs, snakes, and turtles generally occurred in high densities, as reported elsewhere for the Upper Peninsula (Werner and McCune 1979).

Catches of frogs, salamanders, and snakes on the four standard census plots were summarized (Table 6). There was no difference in total catch of frogs and snakes between either pair of plots. The two shallow water sites (A and B) had higher relative densities of frogs and snakes than the two deepwater sites (C and D), indicating that water depth may have been more important than the effects of the burn, at least for these two groups of organisms in lowland areas. All snakes captured in the traps were marsh dwellers except for two smooth green snakes and one red-bellied snake from plot B.

Significantly (X^2, $P < 0.02$) fewer salamanders were caught on the burned plots than on the unburned plots. The upland, hand-collected plots provided further data for salamanders and snakes. There were 78 salamanders and 34 snakes in the unburned plots; the burned plots had 2 toads, 4 salamanders, and 8 snakes. Predominant species in these samples were predictably those associated with upland forests. The density of salamanders was apparently low on all dry upland within the Refuge, but there was also an apparent burn effect, with significantly fewer salamanders (X^2, $P < 0.01$) and snakes (X^2, $P < 0.04$) on burned upland sites.

Upland ponds were sampled in spring for egg masses of ambystomatid salamanders. Five ponds in burned plots contained no egg masses but three ponds in unburned plots had 9–15 egg masses (X^2, $P < 0.01$) indicating markedly reduced breeding activity for salamanders in burned uplands.

On site A, 5% of the animals caught were adult, 3.5% on site B, 11% on site C, and 7% on site D. The limited data suggest that there were fewer adults and fewer large adults in burned areas. The only statistically important differences, however, were for common garter snake (*Thamnophis sirtalis*, Fig. 24) and green frog (*Rana clamitans*). There were more large (≥550 mm snout to vent length) adult common garter snakes on unburned areas than on burned areas (X^2, $P < 0.01$), and a *t*-test showed that green frogs were larger in unburned areas ($P < 0.02$).

Large mixed choruses of diploid and tetraploid treefrogs were heard east of Delta Creek Pool, and gravid female

smooth green snakes and common garter snakes were seen basking around log piles nearby. A survey of the heavily burned spruce area NNW of C_3 pool indicated that depressions left by peat fires created breeding sites for wood frogs. Numerous common garter snakes were found in the area including one feeding on a wood frog, the common food of the garter snake in northern marshes (Gregory and Stewart 1975). In this area, the red-backed salamander occurred at consistent but low densities, but only in unburned patches. Newly transformed individuals of both species of *Ambystoma* were found within the burn.

Fourteen leopard frogs were seen in the lush regrowth of grass and aspen in the marsh burn. Green frogs were found in springs. Choruses of toads were heard in the early spring in this area. Three smooth green snakes were recorded, including one sizable adult basking on barren peat in the most severely burned area.

Trapping and observations with binoculars demonstrated exceptionally high densities of painted turtles and snapping turtles within the burn, as might be expected for thoroughly aquatic animals. Watersnakes were recorded only within the burn.

Wood turtles were found in and around the Driggs River. Terrestrial activity by wood turtles was not observed except in the moist river bottomland (which did not burn) in early spring and on unburned upland near marshes 200 m from the river. Five shells of wood turtles were found, four of them within the burn. Three wood turtles were seen in unburned areas, and one track of a wood turtle was observed near Delta Creek. These turtles were most active near the river, but in peripheral areas many may have died as a direct or indirect result of the fire. The Driggs River bottomland supported by far the densest populations of spotted, blue-spotted, and red-backed salamanders on the Refuge, and these were unaffected by the burn. Moist deciduous areas of the Refuge, none of which burned, also supported high densities of red-backed salamanders.

Table 6. *Number of frogs, salamanders, and snakes censused on the four standard census plots, Seney National Wildlife Refuge, Seney, Michigan.*

Location	Frogs	Salamanders	Snakes
Site A unburned	619	10	16
Site B burned	513	1	15
Site C unburned	194	3	10
Site D burned	234	0	13
Combined unburned	813	13	26
Combined burned	747	1	28

Fish

Generally, the same fish species were caught in control and experimental waters, and often more species and individuals were taken per unit effort in the burned areas (Tables 7 and 8). Other than minnows, abundant species were northern pike, yellow perch, and brown bullhead, the same species previously found common in Refuge waters (A. A. Sharp, unpublished data). The sizes caught also were those expected with the gear used. Fish populations were evidently not affected by the fire.

Soils

After 2 weeks in the field studies of litter indicated significant differences related to treatment (Table 9), with decomposition greater on the burned plots. However, these differences had disappeared after 8 weeks in the field. There were significant differences related to vegetation plots at both sampling times. Potentially faster warming of the burned plots in early summer may have accelerated decomposition at that time, but the effect was not sustained.

The basic soil analytical data yielded relatively few important differences on burned versus unburned areas. There were significant differences for manganese in the A-1 horizon ($P \leq 0.001$) and for organic matter ($P \leq 0.01$) and phosphorus ($P \leq 0.05$) in the B horizons. It appears that the fire had little effect on soil chemical properties.

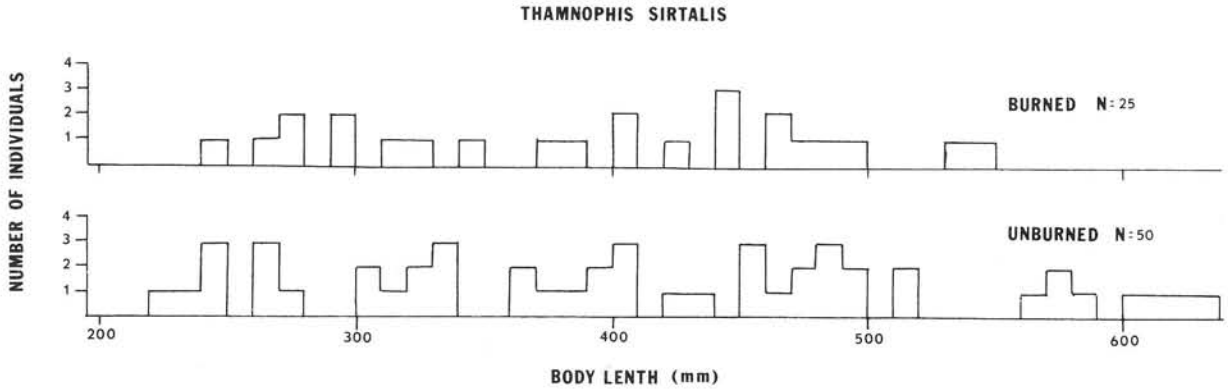

Fig. 24. Comparison of the size distribution of common garter snakes on burned and unburned plots.

Table 7. *Numbers, weights (g), and lengths (mm) of fish caught 17–19 October 1976 in three pools on Seney National Wildlife Refuge (Michigan) in one overnight set of a nylon gill net in each pool.*

Species and pool[a]	Number caught	Total weight (g)	Mean length (mm)	Mean weight (g)
Northern Pike (*Esox lucius*)				
Control (I Pool)	10	17,560	609	1,756
Burned				
Marsh Creek Pool	27	—	437	—
C_3 Pool	15	20,990	563	1,359
Yellow perch (*Perca flavescens*)				
Burned				
Marsh Creek Pool	2	420	252	210
C_3 Pool	9	2,070	252	230
Brown bullhead (*Ictalurus nebulosus*)				
Control (I Pool)	6	285	154	47
Burned				
Marsh Creek Pool	5	183	145	37
C_3 Pool	17	1,830	181	108

[a]No controls (I Pool) for yellow perch; one white sucker (length 400 mm; weight 560 g) was taken in C_3 Pool.

Table 8. *Number of fish caught with a DC electroshocker on 19 October 1976, in three stream sections in Walsh and Marsh creeks, Seney National Wildlife Refuge.*

Species	Control: Walsh above M-28	Burned: Walsh below M-28	Burned: Marsh below M-28
Mudminnow (*Umbra limi*)	5	2	33
Pearl dace (*Semotilus margarita*)	0	0	68
Northern redbelly dace (*Phoxinus eos*)	0	0	58
Blacknose dace (*Rhinichthys atratulus*)	0	0	22
Johnny darter (*Etheostoma nigrum*)	1	0	3
Brook stickleback (*Culea inconstans*)	1	0	5
Blacknose shiner (*Notropis heterolopis*)	0	0	7
Bluntnose minnow (*Pimephales notatus*)	0	0	2
White sucker (*Catostomus commersoni*)	0	0	4
Sculpin (*Cottus* sp.)	1	4	0
Northern pike (*Esox lucius*)	3	2	1

The most striking differences among the sample areas occurred in the B horizons. The highly significant differences among plots in terms of exchange acidity were possibly explained by the coniferous vegetation that predominated on the spruce and Walsh plots (highest exchange acidity), and the aspen and birch that predominated on the Creighton and Driggs plots.

Soils sampled were generally characterized by low pH's but those of the spruce and Walsh plots were consistently lower than the others. The close correlation between organic matter and nitrogen helped explain why both characteristics were either significant or were not within any one horizon. Creighton plots had lower organic matter in both the A-1 and A-2 horizons than did any other plots except spruce A-2. Lower organic matter was noteworthy because both Creighton burned and unburned plots were wetter than all other plots.

Differences among vegetation types showed that maximum accumulation of calcium, magnesium, manganese, and sodium in the B horizons occurred in the Creighton plots. Accumulation of potassium was greatest in the B horizon of spruce plots. The A horizon differences were not as consistent. Perhaps because of the dryness of the Driggs plots, there were higher concentrations of potassium and manganese in their A-1 horizon. Both Creighton and Driggs plots had higher concentrations of sodium in their A-1 horizons than the other plots. These differences were probably due to a combination of coniferous or deciduous vegetation on dry or moist soils.

Results of the soil studies reported here indicate (1) the infertile nature of the mineral soils of Seney National Wildlife Refuge and (2) the very minor impact that burning had on the mineral soils. Samples were not taken until 3 years following the fire (two growing seasons); consequently, effects of short duration would not be detected. However, sustained effects should have been detected and virtually none were found. Burned plots had, in B horizons, higher levels of phosphorus and organic matter than unburned plots. This difference may indicate that there had been some leaching of those materials from the A horizon after the fire.

Table 9. *Amount of leaf disc remaining (original area 15.2 cm²) in litter bags placed in Seney National Wildlife Refuge, 1979. Tabulated data are means of 10 observations.*

Site and Treatment	Amount (cm²) lost after 2 weeks	Amount (cm²) lost after 8 weeks
Creighton		
Burned	8.7	13.6
Unburned	8.6	13.1
Driggs		
Burned	11.9	14.9
Unburned	7.9	12.8
Spruce		
Burned	7.8	10.0
Unburned	5.1	11.4
Walsh		
Burned	4.9	12.4
Unburned	5.2	13.9

Table 10. *Hydrogen ion activity (pH, alkalinity, conductivity, total hardness ($CaCO_3$), calcium, magnesium, sodium, potassium, nitrite–nitrate nitrogen, ammonia nitrogen, total phosphorus, and dissolved phosphorus at 11 selected sites on or near the burned area of Seney National Wildlife Refuge, Seney, Michigan, 16 October 1976.*

Sample Site	pH[a]	Alkalinity (mg/L)	Conductivity (μ mho/cm^2)	Total hardness (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Nitrite–nitrate (mg/L)	Ammonia (mg/L)	Total phosphorus (mg/L)	Dissolved phosphorus (mg/L)
Creighton River Upstream	7.1	90	175	90	24	5.4	1.1	0.5	42	46	16	14
Creighton River Downstream	7.2	80[a]	170[a]	90[a]	23[a]	5.0[a]	1.2[a]	0.6[a]	42	38[a]	11[a]	9[a]
Marsh Creek Upstream	7.3	90[a]	165	90	25	3.1	1.5	0.6	23	164	17	14
Marsh Creek Downstream	7.4	70	140[a]	70	19	3.0	1.2	0.8	98	1,143	36	10
Walsh Ditch Upstream	7.2	90	170[a]	90[a]	24[a]	3.8[a]	1.7[a]	0.8[a]	82[a]	85[a]	20[a]	14[a]
Walsh Ditch Downstream	7.3	90	140[a]	90	27	3.7	1.4	0.7	21	513	39	10
C_3 Pool Eastern	7.4	80	155[a]	90	21	3.7	2.0	0.9	154	122	41	25
C_3 Pool Central	7.4	70	150[a]	70	21	3.7	2.2	1.0	164	–	40	7
C_3 Pool Western	7.4	70	163[a]	90	24	3.9	1.7	0.7	49	58	23	21
Marsh Creek Pool	7.6	28[a]	663[a]	80	8	1.4	1.1	0.8	42	891	32	12
Manistique River	7.5	55[a]	128[a]	75	20	4.3	1.4	0.9	66	34	14	6

[a]Mean of measurements of duplicate samples.

However, this hypothesis was difficult to support because similar differences in cations (i.e., calcium and potassium) were not found and those differences should also have been present. Three years after it occurred the fire appeared to have caused very few differences in soils.

Water Chemistry

Hydrogen ion activity (pH), alkalinity, and conductivity were similar in all waters, both within and outside of the burned area. All waters investigated were alkaline; the pH ranged from 7.1 at CR1 to 7.6 at Marsh Creek Pool (Table 10). The mean pH was 7.3. Total alkalinity as $CaCo_3$ ranged from 28 mg/L at Marsh Creek Pool to 90 mg/L at CR1, MC1, WD1, and WD2, and averaged 74 mg/L. All alkalinity was in the bicarbonate form. The waters sampled were soft. Total hardness, as $CaCO_3$, ranged from 30 mg/L at MCP to 70–90 mg/L at all other stations and averaged 80 mg/L. The waters of Marsh Creek Pool had the lowest alkalinity, conductivity, and total hardness, and the highest pH. This pool was very low due to drawdown and waters were confined to borrow pits along the retaining dike. The recorded measurements suggested that water level in this pool was probably being maintained by groundwater flow.

Calcium was the major cation (Table 10). The relative proportions of calcium, magnesium, sodium, and potassium were similar to the proportions found in most rivers of the world. Concentrations of cations were low. Apparently most cations had been removed from solution through adsorption on peaty organic materials, especially at MCP, where the water level was evidently maintained through groundwater flow.

The major anion was bicarbonate (see alkalinity). Concentrations of sulfates were somewhat lower than usually found in bicarbonate waters of similar specific conductance and alkalinity, especially when compared with concentrations of chlorides. There was a tendency in bicarbonate waters for bicarbonates, sulfates, and chlorides. The low sulfate concentrations in the waters sampled may have been due to very low concentrations in the source material or to organically precipitated ferrous sulfide in peat deposits.

Phosphates and nitrates were more variable among stations than were the other ions measured (Table 10). Concentrations of total phosphates were slightly higher than would be expected in dilute waters. The relatively high proportion of dissolved sestonic phosphate suggested that much of the phosphate was associated with brown organic matter. Brown-water lakes with much peat in their basins were typically higher in soluble phosphates than were clear-water lakes in the same area.

The various forms of nitrogen interact in very complex ways. The determinations made were of total ammonia (mainly NH_4), and of combined nitrite (NO_2) and nitrate (NO_3). Higher concentrations of ammonia were found in stagnant waters such as Marsh Creek, especially at the

stations below the dike on C_3 Pool, and at MCP. These high concentrations of ammonia probably reflected ammonification of organic materials by heterotrophic bacteria. Goose droppings may have been of special importance as a source of nitrogen in some of these waters. Concentrations of nitrite–nitrate were generally similar to those of ammonia in flowing waters and the large C_3 Pool, and were much lower than those of ammonia in stagnant waters. The relatively large quantities of ammonia in the brown waters of Marsh Creek, Walsh Ditch below the dike on C_3 Pool, and in MCP may have been bound to colloidal organic particles.

Results of chemical analyses did not show any effect of the fire on water quality. Limited rainfall and runoff after the fire probably precluded any significant effect.

The fire has had no effect on water quality or on flora and fauna in the water. Snowmelt each year will carry increased concentrations of some ions, especially of potassium and sodium, and will possibly carry substantial quantities of charred organic material into the streams and pools. These materials probably will not severely degrade water quality, or create any deleterious effect on the fish and wildlife resources using the water. On this extremely flat terrain, the interrupted pattern and low intensity of fire (especially along the watercourses) mitigated the potentially deleterious effects of fire on the aquatic resource.

Discussion

Fish and Wildlife Service biologists had the unique opportunity to use the Refuge as an outdoor laboratory to study the burned habitat and its effect on wildlife. The results were similar to other fire studies done in the north-central forests, indicating a decrease in the diversity of bird species in burned areas. Changes also occurred in composition of mammal communities. Unfortunately, most other studies have concentrated on single groups of organisms, such as birds or mammals, or a species (i.e., deer or bear). The study of the Seney fire has been comprehensive, including all wildlife species and, because permanent plots were established, has provided a basis for future study of effects of fire on wildlife and wildlife habitat.

The results of this study provided evidence that fire was of benefit to wildlife species in the region. Data support the results put forth by Jenkins (1946) that fire in the Lake States, particularly Michigan's Upper Peninsula, was a useful tool for attaining two objectives of wildlife habitat management: (1) maintenance of open areas and (2) control of the size and density of woody cover. Both of these objectives were important in the maintenance of wildlife species on the Refuge.

Relationship to Other Studies

The ecological characteristics of the north-central forests, including the forests of the Upper Peninsula, have been determined to a large extent by fire. Forest succession, for example, was controlled by fire on Isle Royale in Lake Superior (Hansen et al. 1973). Frissell (1973) showed that the original biotic community of Itasca Park in Northern Minnesota was influenced by periodic disturbances from fire. When fire control policies were initiated after the establishment of the Park, the characteristics of the community, and thus the wildlife, changed. Ahlgren and Ahlgren (1960) found that pine species in Itasca Park were more or less dependent on fire; however, suitable conditions for reproduction, the necessary combinations of minerals, seeds, reduced shrub competition, and overstory had not occurred in recent years. The result was a decrease in pine regeneration. Ahlgren (1976) pointed out that red pine may not have benefited from fire because it reproduced best on mineral soils with moss and litter. The red pines appeared to be inhibited by ash. Jack pine and white pine, in contrast, tolerated ground ash. Fires tended to result in propagation of aspen rhizome networks underground. Aspen and spruce seemed to do particularly well after fire.

Long-term Effects

The overall effect of the Seney Wildfire was to create greater diversity of wildlife habitat on the Refuge by setting back natural succession. Elimination of understory and creation of snags, downed logs, and edge were part of this change. Vegetation structure was the major wildlife habitat component affected by fire. These structural changes were most pronounced in bog fen where the fire burned deeply in some areas creating caverns. These burn patterns will remain for many years. In the bog forest and on sand islands, trees died as the fire destroyed the shallow roots. Some of the bog forests were burned to the ground and in other areas the trees remained standing as snags or fell haphazardly.

The humus supporting the trees and the bog fen took hundreds of years to accumulate. Mosses and lichens have helped to stabilize the exposed sand. As grasses became established, stability increased. During the third year after the burn, some of the bog-type vegetation reappeared. However, many fire-free years of humus deposition will be required before trees become reestablished in bogs and on sand islands.

The fire burned erratically in the mixed forest area, destroying most of the vegetation in some areas and only burning around tree bases in others. Quaking aspen and jack pine seedlings, as well as blueberry and bracken fern, grew rapidly on the ground in the spring following the fire. The mixed forest will continue to become more dense and change in composition as the years pass. The shallow rooted trees will reestablish and eventually the habitat and wildlife population will reach the pre-fire level. These changes will probably occur over 10–15 years, assuming there are no additional fires.

Wildlife changes will follow the succession in the plant

communities. Characteristic wildlife species for each successional sere will appear both in the forested and marsh–fen habitats. Sharp-tailed grouse, common snipe, and woodcock will decline in numbers as grasslands change to dense shrub communities. As the early plant colonizers such as blueberry and sedge species decline, food for bear will be less prevalent and bobolinks will disappear. Black-backed three-toed woodpeckers will not be easily sighted on the Refuge after 5 years or so when the snags decay. If the Refuge is preserved status quo, overall wildlife diversity will decrease in the next 15 years.

Fire and Wildlife Management

Managers of wilderness areas in the United States and Canada have generally followed the policy of allowing fires to burn as long as the public or adjacent lands are not jeopardized (Alexander and Dube 1982). A number of federal land-managing agencies utilize fire in their overall management plans (Everhardt 1977; Lotan 1977; Wilson 1977; Davis 1979; Nelson 1979). Fire exclusion carries the risks of fuel accumulation to such an extent that widespread, high-intensity fires and consequently loss of flora and faunal diversity result (Alexander and Dube 1982). Fire may assist in preventing the spread of disease to vegetation and wildlife and reducing parasitism in some species (Bendell 1974).

Although some writers described the fire's destructive effects on wildlife (e.g., Kirkpatrick 1941), they often ignored the obvious problem of air pollution (Fahnestock 1973). When fire is used today to maintain wildlife habitat, the benefits of opening habitat quickly must be considered along with the detrimental effects of air pollution. Fire can be an effective tool in some regions when its use is understood in relation to the local natural conditions and when there is proper planning (Fahnestock 1973). Fire must be integrated into the total land-management practices (Lotan 1979), and interests of neighboring landowners must also be considered.

Foresters, wildlife managers, and the general public have different opinions of controlled burns. Foresters tend to seek a hot burn to eliminate as much dead debris as possible and wildlife managers use a cool burn for habitat manipulation. Cool burns destroy only some of the surface litter and are used early in the season so new grass can grow (Purdom and Anderson 1980). Wildlife managers also like fires that produce erratic edge patterns, leaving much standing and downed debris for wildlife shelter and food.

From a wildlife perspective, it is important to consider the total habitat concept. Thus, management of smaller areas (less than 8 ha) by clear-cutting or through fire can affect wildlife populations. By using controlled burns in and around mature forests, managers can maintain a diversity of wildlife.

Fire as a wildlife management tool requires careful consideration in terms of the biotic community and its successional stage. Consideration must also be made of the climatic conditions. Jenkins (1946) pointed out that, in the Upper Peninsula, fire immediately following a logging operation has a greater effect on the succession of vegetation, and thus on wildlife, than a fire occurring in later successional stages. An early fire tends to produce a persistent stage in succession, whereas later fires tend to prolong a seral stage by retarding succession and slowing progression toward the climax. Fire, therefore, can become a means of maintaining wildlife habitat on Seney National Wildlife Refuge. Although comprehensive management plans for all wildlife cannot be prescribed, based on one small fire, several ideas can be considered.

The Refuge is a very small component of the north-central ecosystem. In effect, the fire is a small phase in the total picture of changes that can occur in wildlife habitat. The fire, however, shows that the Refuge, if unburned for long periods of time, is likely to develop a fire from natural causes. The tremendous amount of debris that accumulates on the ground, plus the standing dead vegetation, all add up to an explosive fire hazard. Thus, small controlled burns could be an effective means of preventing large wildfires.

Controlled and carefully monitored small burns could provide managers with data on how to best utilize fire in this region. The Refuge, with its natural boundaries of rivers, lakes, and forest edge, provides an excellent place for a controlled study of fire as a management tool. It is also important to realize that the total diversity of wildlife is higher on the Refuge following the fire even though it is lower on the burned area. Thus, in terms of Refuge objectives, fire might be used as a tool to maintain wildlife species for public enjoyment.

Completion of Objectives

Our 3-year study showed that fire structurally changed the habitat allowing the reestablishment of wildlife species. Disturbances such as fire were common years ago. The size and configuration of the habitats, along with structurally altered habitat, had been changed with an increase in the edge of many habitats, further changing species composition.

No species was completely destroyed or eliminated because no habitat was completely destroyed. Aerial photos and field observations showed that changes were still occurring in the habitat 3 years after the fire. Some tree species, for example, had green vegetation for 2 or 3 years after the fire and then died. Meanwhile, new plants became established on the burned areas each year after the fire. Thus, an immediate assessment of the total impact of fire was not possible.

Vegetation in the burned areas was recovering rapidly because nutrient levels remained virtually unchanged. Grass was quickly replaced by sedges, seedlings, and shrubs. These early stages of succession could be documented easily as colonizers moved in. Future changes will be more noticeable in vertical rather than horizontal stratification.

Permanently marked plots are established in the burned area to continuously measure future changes in the habitat. These changes can be recorded on the vegetation map prepared in this study. Bird censuses and mammal surveys also can be taken on the same areas that were utilized for this project.

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