SMALL MAMMAL USE OF ABANDONED

SURFACE MINES IN SOUTHWESTERN VIRGINIA

by

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INTRODUCTION

Coal is an important source of energy in the United States today. It currently supplies approximately 18 percent of the nation's energy requirements. Its most important use is as a fuel in the generation of electrical power, where it comprises 44 percent of the fuel so utilized (Council on Environmental Quality 1973). Surface mining accounts for half of the current U.S. coal production, however only a small percentage of the nation's total coal reserves are ultimately mineable by surface methods (Council on Environmental Quality 1973). This emphasis on surface mining is due largely to its greater cost efficiency in comparison to deep mining. Coal in general, and surface mining in particular, promise to become even more important in the near future as the U.S. expands its use of coal to relieve its dependence on dwindling supplies of oil and natural gas. A majority of the surface mineable coal lies in thick and, as yet, relatively unexploited seams in the western United States.

Surface mining involves the removal of the soil and rock layers (the overburden) above the coal seam and the subsequent excavation of the coal. The overburden is deposited nearby, forming what are known as spoil banks. Two major kinds of surface mining for coal are practiced in the U.S. today. The first, called area mining, takes place in relatively flat terrain. In this method, successive, parallel swaths of overburden and coal are removed. The overburden from the active cut is placed in the pit left by the previous cut. The resultant topography consists of a series of parallel ridges and valleys. The second major method of surface mining is called contour mining. This method is practiced in mountainous terrain such as occurs in southwestern Virginia. In this method, the more or less horizontal coal seam is followed along a mountainside. The overburden is removed and deposited downhill from the cut. Mining continues into the hillside until the overburden becomes too thick to be removed economically. The spoil bank downhill from the mining cut is called the outslope, the flat bed left after removal of the coal is called the bench, and the cliff present where mining ceased is called the highwall (Fig. 1). The resultant topography from this method of mining resembles a road cut along the side of a mountain. Contour mining is the major method of surface mining practiced not only in southwestern Virginia, but also in the rest of Appalachia.

During the 1960's, most states where surface mining occurred enacted legislation requiring mine operators to reclaim surface mines after the coal was removed. Virginia passed such a law in 1966 (Boccardy and Spaulding 1968). Prior to enactment of these laws, most surface mines were simply abandoned after mining without any attempts being made by the operators to revegetate or regrade the areas. No provisions were included in the laws, however, for reclaiming abandoned, pre-law mines. As of 1972, over 2 million acres of these abandoned lands existed in the United States (Council on Environmental Quality 1973). They continue to pose environmental problems, contributing silt and acid to streams as well as being esthetically displeasing scars on the landscape. Natural vegetation has invaded some of these mines, but others have remained essentially bare even after 10 to 15 years.

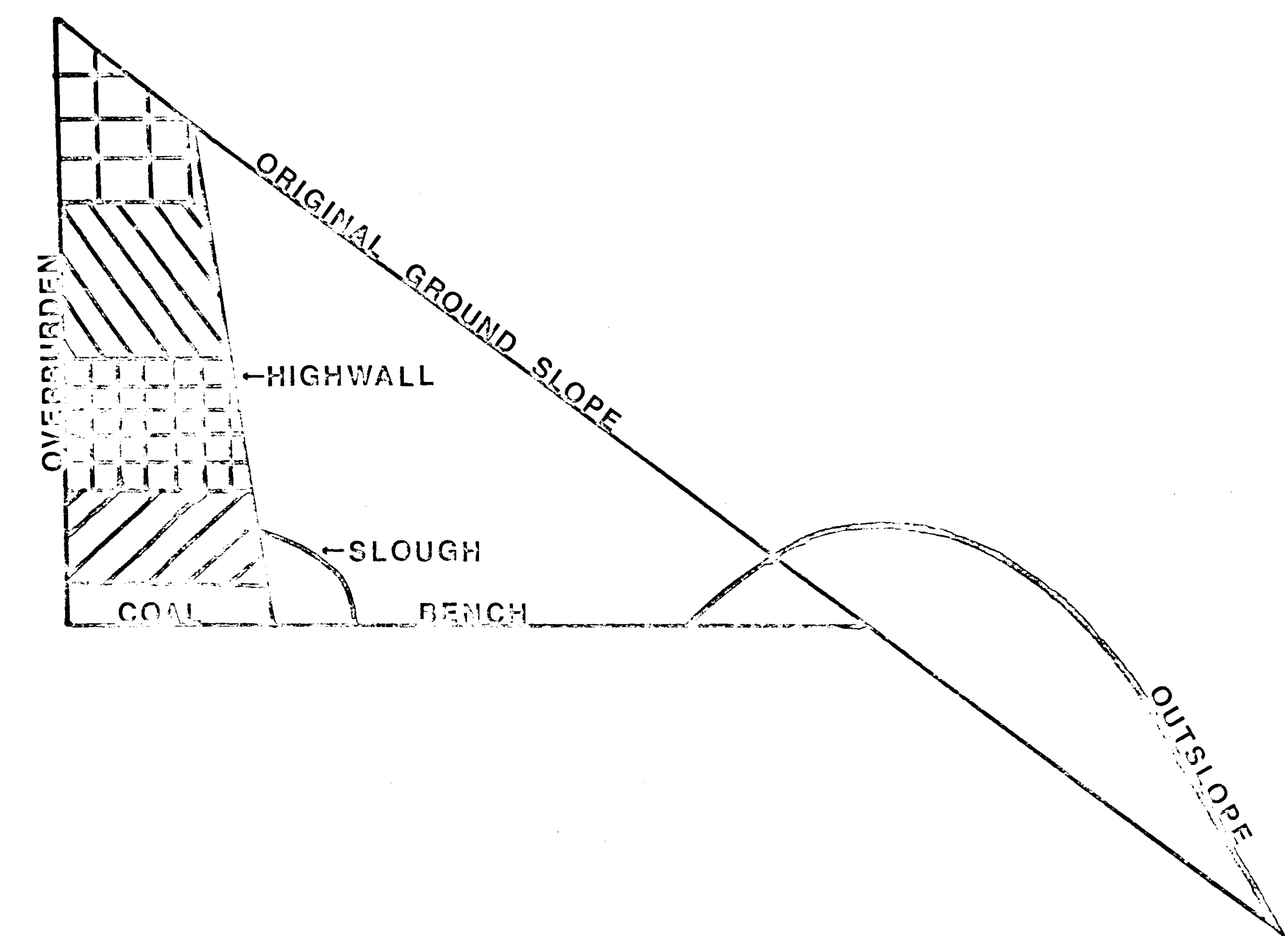

Fig. 1. Cross-section of a contour surface mine, after Grim and Hill (1974).

Funds are currently available in Virginia and several other eastern states for reclamation of abandoned surface mines. The probability of additional funding in the future is high. Not all abandoned mines are in need of reclamation, however. Some mines have completely rehabilitated naturally. It would be a waste of money to destroy useful vegetation by reclaiming these mines, since most reclamation will temporarily destroy many favorable conditions that have developed over the years. On many mines the decision whether to reclaim or not is less clear-cut. Not enough is known about these mines to determine if the benefits from reclamation will outweigh the temporary damage that will be done by redisturbing the area. Information is needed, therefore, on the conditions prevailing on these abandoned mines. Both abiotic and biotic factors are important. Once these conditions are known, better decisions can be made as to how the reclamation funds can be spent to achieve their maximum net benefit.

In the past, most reclamation has been aimed at ameliorating adverse off-site environmental impacts of surface mines, such as stream acidification and siltation. This so-called basic reclamation has not been designed to impart any higher value to the land than it possessed prior to mining. Much has been said about the merits of developing surface mines as recreational areas, however, most of this talk and the few successful areas so developed have involved area, not contour mines. Major problems are often encountered in this type of reclamation effort and the idea is not a panacea (Roseberry and Klimstra 1964). Where hunting and trapping are concerned, the reclamation necessary to produce harvestable wildlife populations can be very expensive (Arata 1959) and the investment may not be justified because of low levels of public use (Bookhout et al. 1968, DeCapita and Bookhout 1975, DeCapita 1975). These considerations become increasingly important in remote, mountainous areas of Appalachia, such as southwestern Virginia. Here, anything more than basic reclamation is normally infeasible and the mitigation of environmental damage is the highest readily perceived reclamation goal.

Most basic reclamation plans have not included wildlife considerations as an important input to the decision-making process. It has more or less been assumed, as Spaulding and Ogden (1968) have noted, that wildlife will benefit from any reclamation program that eliminates adverse environmental conditions. While this may be true, significant improvements in a reclamation program's impact on wildlife could be realized if wildlife was given consideration during formulation of the program, rather than being tacked on as an afterthought. If basic reclamation and wildlife restoration are indeed complementary, then this might be achieved without spending any additional reclamation funds.

The improvement of a reclamation program's impact on wildlife is a desirable goal from at least two standpoints. First, wildlife is an integral part of any ecosystem, no less important nor less deserving of consideration than the air, soil, water, or vegetation. If we are to take a holistic approach to the reclamation problem, then we must include wildlife in the formation of reclamation strategies. Secondly, wildlife should be included in reclamation plans if for no other reason than to maximize the cost effectiveness of each reclamation dollar.

Among the wildlife components of a terrestrial ecosystem, small mammals constitute an inconspicuous, but nevertheless important segment. They are important components in the diets of many carnivorous mammals and raptorial birds, as well as being important consumers in their own right (Martin et al. 1951). They thus have an important role in the trophic structure of any community. They are also important in nutrient cycling and play a role in soil development and subsequent plant growth. Their burrowing activities assist in mixing, loosening, aerating, draining and fertilizing soils, thereby improving conditions favorable to plant growth and hence promoting soil conservation (Bond and Borell 1939). Their role in soil improvement may be especially important on abandoned surface mines where poor revegetation success is a direct result of adverse physical and chemical spoil properties (Ashley 1950, Bramble and Ashley 1955, Byrnes and Miller 1973, Horn 1968). Information on which species of small mammals use abandoned surface mines and which site conditions are needed for maximum small mammal diversity and abundance can, along with other wildlife data, provide the needed information for formulating more optimum abandoned mine reclamation strategies.

The objective of this study was to determine the relationships between small mammal diversity and abundance and certain vegetation and site factors on abandoned surface mines in Virginia. It was part of a much larger project, supported by the Office of Biological Services, U.S. Fish and Wildlife Service, concerned with identifying reclamation needs of abandoned eastern surface mines. The goal of this larger project is to develop a computer-based decision-aiding system for abandoned mine reclamation decision-making. The system will take into account a vast array of considerations and determine a site-specific reclamation prescription for an abandoned mine. The current study was designed to provide part of the input for this system. Other students are working on different aspects of the same project. Haufler (1976) has already dealt with the vegetation component and identified factors which most influence natural revegetation on abandoned mines in Virginia. Through such studies it is hoped that a system can be developed which will begin to solve the difficult problem of abandoned mine reclamation.

LITERATURE REVIEW

Several studies have dealt with the effects of habitat disturbance on small mammal populations. These studies generally indicate that certain species of small mammals (particularly *Peromyscus* spp.) not only utilize disturbed areas, but prefer them to surrounding undisturbed habitat. Clements and Clements (1940) noted that, in general, rodents prefer disturbed areas in grasslands. This preference was attributed to an abundance of forbs in the disturbed areas which provided a preferred food supply for the rodents. In Oregon, Gashwiler (1959) found that *Peromyscus* populations were greater on logged and burned areas than in the undisturbed forest nearby. Tevis (1956) found increased *Peromyscus* populations on a clearcut area after the slash was burned. In Virginia, Crandall and Chamberlain (1963) found the same species of small mammals in disturbed and undisturbed forests, but populations of *Peromyscus* were greater in the disturbed forests. In their study, the highest *Peromyscus* population was found in the youngest disturbed forest.

A number of people have studied the effects of surface mining on wildlife and concluded that surface mines often afford better habitat for some wildlife species than surrounding unmined land. Unfortunately, most of the information has been gathered from areas where area mining is practiced and may not be applicable to the contour mines of Appalachia. Yeager (1942) conducted a general survey in Illinois and found several species of mammals abundant on surface mined land. He stressed the value of the mines for wildlife production and their possible sanctuary role owing to their relative inaccessibility. Riley (1953, 1954) conducted studies in the Midwest, comparing wildlife populations on reclaimed surface mines and adjacent cropland, abandoned cropland and forestland. He found that cottontail rabbits (Sylvilagus floridanus) were more abundant on the reclaimed surface mines than on any of the surrounding land, while woodchucks (Marmota monax), raccoons (Procyon lotor), grouse (Bonasa umbellus) and quail (Colinus virginianus) were at least as abundant on the mines as on surrounding land. The surface mines were also found to contain more species than surrounding land. Riley felt the reason for this was that, although food and cover were abundant on the mined land, cover was deficient on the cropland, food was deficient on the abandoned cropland, and both food and cover were deficient in the forest. In Indiana, Jones (1967) found that opossums (Didelphis marsupialis), cottontails, woodchucks and red foxes (Vulpes fulva) were at least as common on surface mined land as on surrounding land. He attributed this to abundant food and cover, as well as good interspersion of cover types on the mined land. Collins (1956) noted the high use intensity of surface mines by wildlife and advocated certain reclamation measures which would enhance this capacity of the mines.

Similar wildlife information is noticeably lacking where contour mines are concerned. Holland (1973) purported to study wildlife benefits from contour surface mine reclamation, but in the end could make no reliable comparison of wildlife use between reclaimed and unreclaimed areas. He did note, however, that reclamation aided in speeding up vegetation development on the mines. Fowler and Peery

(1973) documented the development of a public use wildlife area on a contour surface mine in southwestern Virginia. Trees and shrubs of special value to wildlife were planted on the area to augment the natural vegetation which was already present. Cottontail rabbits were the primary game species utilizing the mined area, however wild turkeys (Meleagris gallapavo) and white-tailed deer (Odocoileus virginianus) were stocked in the area in an attempt to establish resident populations. Turkeys were still present in the area 3 years after the initial stocking. The deer, however, quickly disappeared, possibly as a result of harassment by free-ranging dogs. Dudderar (1973) stressed the opportunity for wildlife habitat improvement through contour mine reclamation. He also outlined some basic reclamation practices designed to achieve that goal.

A few studies of small mammaluse of surface mines have been conducted, but no work has been done in areas where contour mining is practiced. Wetzel (1958) described mammalian succession on a surface mined floodplain in Illinois. He found the prairie deer mouse (Peromyscus maniculatus baiirdi) entirely responsible for the increase in small mammal abundance during the first 7 years after mining. In the mid-seral stages, prairie voles (Microtus ochrogaster), short-tailed shrews (Blarina brevicauda) and white-footed mice (Peromyscus leucopus) were the most abundant species. The late seral stages were dominated by white-footed mice and short-tailed shrews. Verts (1957, 1959) also studied the mammals of a surface mined area in Illinois. He found certain species, particularly the prairie deer mouse, were characteristic of the most recently mined areas, while other species, particularly the white-footed mouse, were characteristic of older areas. Some species were distributed throughout the mined areas irrespective of the time since mining. He could arrive at no satisfactory explanation for the observed distribution patterns of the two species of Peromyscus. He ruled out successional vegetative differences between young and old areas since there were no measurable vegetative differences between the two types of areas other than an increased height and diameter of trees in the older areas (Verts 1957). Bookhout et al. (1968) studied the small mammals of a large area in Ohio, a portion of which had been surface mined. Faunal diversity was lower on surface mined land than on adjacent unmined areas, however Peromyscus spp., cottontail and woodchuck populations were at least as large on the surface mined land as on the unmined areas. In a follow-up study, designed to determine the effects of limited reclamation on mammal populations, it was determined that most mammal populations had increased in size throughout the study area (Decapita 1975, DeCapita and Bookhout 1975). It could not be stated, however, that this was in any way related to the reclamation work that had been done. White-footed mice and cottontails were again at least as abundant on surface mined land as on unmined land, but this time woodchucks were found to be more abundant on unmined land. It was concluded that the surface mined areas offered adequate small mammal habitat, but, when compared to early successional stages on unmined land, were deficient in terms of overall community diversity. In Indiana, Mumford and Bramble (1973) compared small mammal populations on surface mined land to those on adjacent unmined land and cropland.

They found Peromyscus leucopus to be the most abundant small mammal. Populations of this mouse were two to three times greater in all cover types on mined land than on unmined land or cropland. Eight other species of small mammals were captured in the study and only one of these species was not represented on the surface mined land. Jones (1967) also found that P. leucopus populations were two to three times greater on surface mined land than on surrounding unmined land in Indiana. Not only were these mice abundant, but they were captured in a wide variety of habitat types on the mines. Several other species of small mammals were also captured during the study (P. maniculatus, Mus musculus, Microtus ochrogaster, Blarina brevicauda, Sorex spp.), however, with the exception of Blarina brevicauda, these species were more abundant on unmined land than on mined land. The greatest number of species was found to occur in an unmined herbacecus habitat. Sly (1976), also working in Indiana, found P. leucopus and P. maniculatus to be the most abundant small mammals on surface mined land. P. maniculatus was found only in areas where there was poor woody plant cover. P. leucopus, on the other hand, preferred areas with good woody plant cover, although they were not restricted to these areas. Herbaceous cover did not appear to be a factor limiting the distribution of either species. Sly also determined that P. maniculatus preferred areas with coarser soils, lower soil moisture and higher soil pH, when compared to P. leucopus. Where the two species occurred together, however, they exhibited random distributions, indicating that antagonism was not a factor in habitat selection.

One small mammal study has recently been conducted that involved surface mines other than coal surface mines. Kirkland (1976) sampled small mammal populations on spoil banks resulting from open pit titanium and iron mines in New York, and compared populations from the spoil banks with those from the surrounding forest. He found seven species of small mammals inhabiting the spoil banks, compared to 13 species in the surrounding forest. The woodland deer mouse (Peromyscus maniculatus gracilis) was the most abundant and widespread small mammal on the mine waste areas. It was the only small mammal that was at least as abundant on mined land as it was in the surrounding forest. Kirkland concluded that the woodland deer mouse exhibits a broad ecological tolerance since it can successfully exploit the sparsely vegetated mine waste areas, which are very different from its normal forest habitat.

In general then, past research has shown that, when compared to surrounding unmined areas, surface mines offer adequate habitat for most species of mammals. For some species, particularly Peromyscus maniculatus and P. leucopus, surface mines appear to offer better habitat than surrounding unmined land. Where the two species occur together, P. maniculatus has been found to be primarily associated with the early successional stages on the mines, while P. leucopus has been found to prefer the later successional stages. Mice of the genus Peromyscus have been shown to be able to utilize extensively many types of disturbed habitats other than surface mines. These mice appear to exhibit a broad ecological tolerance which permits them to exploit disturbed habitats to a greater extent than most other mammalian species. Most past research has been conducted in the Midwest where area mining is practiced and it is not known to what extent results obtained from these studies can be applied to contour surface mines in the eastern U.S.

MATERIALS AND METHODS

Description of Study Area

The abandoned contour surface mines used in this study were located along the Clintwood coal seam in Wise, Dickenson and Buchannan counties in southwestern Virginia. This area is in the Cumberland Mountains and lies in the ecotone between the Mixed Mesophytic Forest region to the west and the Oak-Chestnut Forest region to the east (Braun 1950, Shelford 1963). The elevation of these counties ranges from 1,500 ft. (457 m) to 3,000 ft. (914 m). Sharp mountain ridges and narrow valleys are characteristic of the area. The soils are generally thin, low in fertility and acidic (pH 4.0 - 5.8) (McCart 1973). An average of 44 inches (112 cm) of rainfall occurs in this area annually (Officials of NOAA 1974). Coal mining is the major economic activity. Extensive surface mining of the Clintwood coal seam in these counties prior to the 1966 mining reclamation law has resulted in a wide variety of abandoned mines in different stages of natural recovery. Conditions ranging from a complete lack of vegetation to complete reforestation are to be encountered on these mines. A great diversity of small mammal habitats were thus available for study.

The study was conducted on 12 abandoned contour surface mines. The mines were selected to represent a wide range of revegetation success and successional development. Four mines were assigned to each of three general categories. One category consisted of mines which were relatively poorly revegetated and contained much bare ground. Another group consisted of mines in a relatively advanced stage of revegetation. A dense-growing deciduous forest predominated on these mines. A third group of mines was characterized by an intermediate degree of revegetation. These mines contained large open areas of herbaceous and shrubby vegetation. Eleven of the mines were selected from the mines studied by Haufler (1976). One additional mine in the advanced revegetation category was selected so that there were four mines in each category. It should be noted that the three vegetation categories were very gross generalizations of the vegetation present on the mines. Each mine was really a mosaic of much smaller vegetational units because a great diversity of vegetation types were found on each mine (Haufler 1976). Therefore, even though a mine was classified in one particular category, it should not be construed to be a homogeneous vegetational entity. Although it was dominated by vegetation appropriate to that general category, it undoubtedly possessed small areas where the vegetation more closely resembled that of another category.

Habitat Data

Habitat parameters selected for study were those which were deemed most likely to affect small mammal populations. Certain of these parameters were selected from the habitat data collected by Haufler (1976) for the 11 mines used in his study. Identical habitat data were collected for the twelfth mine using the same methods. The following procedures were employed:

1. The mine was divided into units of similar vegetation. Obvious differences in soil, slope,

and aspect were used to a lesser extent to delineate units. These units were sketch-mapped in the field and received a brief, general description

2. Stem counts of woody vegetation were made along a transect 2 m wide and at least 25 m long in each vegetation unit. The length of the transect varied with the size of the unit, being longer in units of greater area. For units too small to accommodate a 25 m transect, complete stem counts were made. Stems were counted in the following size categories: less than 1 m in height, 1-2 m, 2-4 m, 4 m in height to 7.6 cm DBH, and greater than 7.6 cm DBH. These stem counts were later expressed in units of stems per 100 m^2.

Soil data for each vegetation unit were available for the 11 mines studied by Haufler, but no soil samples were collected on the one mine unique to this study. The soil samples had been analyzed for pH, soluble salts, calcium, magnesium, phosphorus and potassium. Data for one other variable, namely the number of plant species in each vegetation unit, were available for 11 of the mines, but were not collected on the new mine.

In addition to the above data, certain new information was collected on all 12 mines. These data were collected at the same time of year (July and August) as the data collected by Haufler so that they would be congruent with his data. The following were estimated for each vegetation unit:

1. Total percent ground cover of all vegetation.

2. Percent herbaceous ground cover.

3. Percent woody ground cover.

4. Percent vegetation volume in each of the following height strata: less than 1 m, 1-4 m and greater than 4 m. These estimates were then weighted by multiplying the volume percentages by the heights of their respective strata. This was done to make the percentages more representative of true volumes.

5. A relative estimate of rockiness. Each unit was assigned a number from 0 to 10, with 0 representing the absence of rocks and 10 representing a rock pile. A rock was considered any stone larger than 10 cm in diameter.

Several new woody stem and vegetation volume variables were created from the variables already mentioned. A total woody stem density per 100 m^2 was obtained by summing the stem densities for all the woody stem size categories. A size diversity index was also calculated for woody stems from the proportions of the total stem density in each size category. The formula of Shanon and Weaver (1963) was utilized for this purpose. A third variable created was a weighted woody stem size diversity index. This was obtained by multiplying the previously mentioned size diversity index by the total woody stem density per 100 m^2. This procedure thus incorporated the elements of size diversity and total woody stem density into one variable. A total volume variable, a volume height diversity variable, and a weighted volume height diversity variable were calculated in the same manner as were the corresponding variables for woody stem density. A summary of all the habitat variables used in the data analysis, their abbreviations and, where appropriate, their method of calculation is presented in Table 1.

Small Mammal Trapping

Kill-trapping and live-trapping were employed to census small mammal populations on the 12 mines. Four consecutive trapping periods were used. Three mines, one from each revegetation category, were trapped each period (Fig. 2). A trapping period consisted of six nights of continuous trapping. The trapping was conducted during the months of June, July and August, 1976.

Kill-trapping was used to sample small rodents and insectivores. Traps were set systematically along parallel transects. The first transect was located along the slough at the base of the highwall and followed the general contour of the highwall. Subsequent transects were located at 10 m intervals from the first one. Parallel transects were laid out over the bench and outslope to within 10 m of the undisturbed habitat below the mine. The transects were 90 m in length. A trapping station was located at the beginning of each transect and at 10 m intervals along the transect, yielding 10 trapping stations per transect and 100 stations per hectare. The trap grid thus sampled the vegetation units in approximate proportion to their size. From the sketch maps of the vegetation units, the location of each trapping station was determined so that the number of stations in each unit, and therefore the number of traps, would be known.

Table 1. Habitat variables used in analysis of trapping data, abbreviations and method of calculation.

Variable	Abbreviation	Method of calculation
Total cover (percent)	TC	--
Herbaceous cover (percent)	HC	--
Woody cover (percent)	WC	--
Woody stem density < 1 m (stems/100 m^2)	WSO	--
Woody stem density 1-2 m (stems/100 m^2)	WS1	--
Woody stem density 2-4 m (stems/100 m^2)	WS2	--
Woody stem density 4 m -3" DBH (stems/100 m^2)	WS3	--
Woody stem density > 3" DBH (stems/100 m^2)	WS4	--
Total woody stem density (stems/100 m^2)	WST	WSO + WS1 + WS2 + WS3 + WS4
Woody stem size diversity	WSD	$- \Sigma p_i \log_{10} p_i$ *
Weighted woody stem size diversity	WWSD	WST x WSD
Weighted vegetation volume < 1 m (percent)	VO	% volume < 1 m x 1
Weighted vegetation volume 1-4 m (percent)	V1	% volume 1-4 m x 3
Weighted vegetation volume >4 m (percent)	V2	% volume >4 m x Height of strata

Table 1. Habitat variables used in analysis of trapping data, abbreviations and method of calculation (continued).

Variable	Abbreviation	Method of calculation
Total vegetation volume (percent)	VT	VO + V1 + V2
Vegetation volume height diversity	VHD	$-\Sigma p_i \log_{10} p_i$ **
Weighted vegetation volume height diversity	WVHD	VT x VHD
Rockiness	ROCKS	--
Number of plant species	NSPP	--
Surface soil pH***	SPH	--
Deep soil pH***	DPH	--
Surface soil calcium (ppm)	SCA	--
Deep soil calcium (ppm)	DCA	--
Surface soil magnesium (ppm)	SMG	--
Deep soil magnesium (ppm)	DMG	--
Surface soil phosphorus (ppm)	SPO	--
Deep soil phosphorus (ppm)	DPO	--
Surface soil potassium (ppm)	SK	--
Deep soil potassium (ppm)	DK	--

Table 1. Habitat variables used in analysis of trapping data, abbreviations and method of calculation (continued).

Variable	Abbreviation	Method of calculation
Surface soil soluble salts (ppm)	SSALT	--
Deep soil soluble salts (ppm)	DSALT	--

* p_i = proportion of total stem density in the i^{th} size category

** p_i = proportion of total volume in the i^{th} height strata

*** Surface soil sample taken from top 2 cm of soil.

**** Deep soil sample taken from 20 cm beneath surface. See Haufler (1976) for description of soil collection method.

Revegetation Category

Trapping Period	Poor	Intermediate	Advanced
1	B*	E	S
2	G	K	R
3	F	P	Z
4	N	M	Y**

* Letter designations for mines identical to those used by Haufler (1976).

** Mine Y not included in Haufler's study.

Fig. 2. Trapping scheme for 12 abandoned surface mines according to trapping period and revegetation category.

A combination of Victor mouse traps, Victor rat traps and pitfalls were placed at the trapping stations. The pitfalls consisted of cans (10.5 cm in diameter X 17.3 cm in depth) sunk flush with the surface of the ground. The traps were placed as follows:

1. At odd numbered stations, three Victor mouse traps were placed within a 1 m radius of the station marker.

2. At even numbered stations, two Victor mouse traps, one Victor rat trap and one pitfall were placed within a 1 m radius of the station marker.

The mouse and rat traps were baited with a mixture of rolled oats and peanut butter. Pitfalls were not baited.

Live-trapping was used to sample mammals too large to be captured by the mouse traps, rat traps and pitfalls. Six wooden box traps (14 X 18.5 X 60 cm) and four metal Tomahawk traps (26 x 32 X 82 cm) were set on each mine. These traps were located only on the bench and at locations deemed most likely to catch larger mammals. The box traps were baited with sliced apples and the Tomahawk traps with canned herring and sliced apples.

All traps were checked once each day. When an animal was captured, the following data were recorded:

1. Trap night (1-6).

2. Transect and station (for kill-trapped mammals only).

3. Vegetation unit where the animal was captured.

4. A brief description of the area immediately surrounding the capture site.

5. Species.

6. Peculiarities about the animal, e.g. general condition, parasites, reproductive condition.

Live-trapped mammals were marked with spray paint and released after the above data were recorded.

Analysis of Data

General Analysis

The trapping data were analyzed to determine which species of small mammals were utilizing abandoned surface mine habitats in southwestern Virginia. General habitat preferences within the surface mines were noted for all species captured. This was accomplished by noting the vegetation units in which the captures were made as well as the descriptions of the habitat immediately surrounding the capture site. Trends in small mammal succession corresponding to the three major vegetative successional categories of mines were also noted. This analysis was largely subjective since the vast majority of species were not captured in sufficient numbers to permit intensive statistical analyses.

Peromyscus Analysis

Members of the genus *Peromyscus* were captured in sufficient numbers to permit a more thorough analysis of the factors affecting their distribution and abundance. Abundance was expressed as trapping success (captures per 100 trap-nights). A trap-night is defined as one trap being set for one night. Trapping success was calculated for each mine and vegetation unit where *Peromyscus* was captured.

A two-way analysis-of-variance was performed to determine if trapping success differed significantly among the four, six-night trapping periods and among the three vegetative successional categories.

Several methods were employed to reveal significant relationships between trapping success and the habitat variables listed in Table 1. All variables were plotted against trapping success to illustrate graphically any relationships that might exist. Correlation coefficients were also calculated to determine any significant relationships. Finally, multiple regression analyses were employed. Trapping success was the dependent variable in the regression equations, while the habitat variables served as independent variables. In addition to the habitat variables listed in Table 1, one other independent variable, namely the number of traps in each vegetation unit, was included in the above three analysis procedures to determine its relationship to trapping success. This variable was a measure of the area of the vegetation units because trap spacing was kept constant on all mines, hence more traps were present in the larger units.

T-tests were employed to reveal any significant differences, in terms of the habitat variables, between the following two groups of vegetation units:

1. Units where trapping success was zero and hence no mice were captured.
2. Units where trapping success was greater than zero and hence mice were captured.

The two groups were treated as independent samples in the calculation of the t-statistics. This analysis was designed to determine which habitat variables were associated with the presence or absence of *Peromyscus*.

With the exception of the analysis-of-variance procedure, all of the above procedures were carried out with the aid of the Statistical Analysis System (SAS) developed by Barr et al. (1976).

RESULTS

General

Eleven species of mammals were captured on the 12 abandoned surface mines during the four, six-night trapping periods. The numbers of each species captured and the mines on which they were captured are presented in Table 2. The actual numbers of mammals captured that appear in Table 2 should not be used in compariosns of abundance between mines because the mines varied considerably in width and any differences in the numbers of mammals captured between mines may thus have been due solely to the different sizes of the mines.

Members of the genus *Peromyscus* were by far the most abundant and widespread small mammals present on the mines. They represented 81 percent of the total mammal catch and were captured on all of the 12 study mines. An average of 15.7 *Peromyscus* were captured per mine. In contrast, rarely were more than one or two individuals of any other species captured on a mine.

For most mammalian species, characteristic habitat types could be discerned where each species was most likely to be captured. What follows is an account of those habitat types for each species. Because members of the genus *Peromyscus* were captured in sufficient numbers to permit a more thorough analysis of the factors affecting their distribution and abundance, that genus will be discussed later in more detail.

Neotoma floridana

The eastern wood rat was captured on three of the mines. They

Table 2. Results of four, six-night trapping periods on 12 abandoned surface mines.

Species	No. captured by mine B	E	S	G	K	R	F	P	Z	N	M	Y	Total no. captured
Peromyscus spp.*	8	13	23	12	8	27	25	18	20	5	15	14	188
Neotoma floridana								4		1	5		10
Blarina brevicauda		2	1	1		1		1	1				7
Didelphis marsupialis		1	1			2				2	1		7
Sorex cinereus						1	1	1	1		2		6
Sylvilagus floridanus		1				1	1		1		1		5
Tamias striatus		2							1		1		4
Mus musculus		2		1									3
Glaucomys volans						1			1				2
Reithrodontomys humulis									1				1

* *Peromyscus leucopus noveboracensis* and *Peromyscus maniculatus nubiterrae*

were captured in brushy or reforested areas and hence were associated with the medium to late successional stages. Furthermore, they were captured only in areas where large rocks and boulders were abundant. Several wood rats were captured alive and, following their release, were observed retreating into crevices and natural dens among the rocks.

Blarina brevicauda

The short-tailed shrew was captured on six of the mines. They were captured in areas which were reforested to varying degrees and hence were in the later stages of succession. Most members of this species were captured in areas where there was a relatively well-developed layer of leaf mold and humus on the ground.

Didelphis marsupialis

The opossum was captured on five of the study mines. They were usually captured in the reforested areas, however they occasionally were taken in more open areas near the forest edge. They were thus associated with the later successional stages encountered on the mines.

Sorex cinereus

The masked shrew was captured on five of the mines. They were captured in nearly every type of habitat found on the mines: bare, rocky areas, herbaceous areas, shrubby areas and reforested areas. Although they appeared to be widely distributed on the mines, they were not abundant.

Sylvilagus floridanus

The eastern cottontail was captured on five of the mines. They were captured in both open fields and reforested areas and hence seemed to utilize a wide variety of successional stages. All the areas in which they were captured were characterized by dense vegetative cover near the ground, however, the type of ground cover seemed to be unimportant. In some cases it consisted of perennial forbs and grasses, while in other cases it consisted of briars and woody vines. This species appeared to be more abundant on the mines than the trapping results indicated, as cottontails and their sign were frequently observed on the mines while checking traps.

Tamias striatus

The eastern chipmunk was captured on three of the mines. They were captured in reforested areas or near the forest edge and hence were associated with the later successional stages.

Mus musculus

The house mouse was captured on two of the study mines. They were captured in open areas dominated by herbaceous vegetation and hence seemed to prefer the early successional stages on the mines.

Glaucomys volans

The southern flying squirrel was captured on two of the study mines. Only two individuals were captured during the study, however both were captured in older reforested areas.

Reithrodontomys humulis

Only one eastern harvest mouse was captured during the study. It was captured in a low wet area whose dominant vegetation consisted of sedges (Carya spp.) and grasses. It is not known if this was a preferred habitat type for this species.

Peromyscus

White-footed mice (Peromyscus leucopus noveboracensis) and deer mice (P. maniculatus nubiterrae) were the most abundant small mammals encountered on the 12 study mines. Captures of these mice greatly exceeded captures of all other species. Not only were these mice abundant, but they were also very widely distributed. They were captured in every conceivable habitat type encountered on the mines. In many of the poorly revegetated areas they were the only small mammals captured. Overall trapping success for the genus Peromyscus was 1.32 mice per 100 trap-nights.

Trapping success was calculated for each mine and an analysis-of-variance test was performed to determine if significant differences in trapping success existed among the three revegetational categories and among the four, six-night trapping periods. The experimental design corresponded to a two-way analysis-of-variance with one observation per cell (Fig. 3). Both the revegetation category and the trapping period factors were fixed effects in this model. The results of the test are summarized in Table 3. Significant differences were observed between the three revegetational categories ($p = 0.05$), however no significant differences were observed between the four

Factor A: Revegetation Category

Factor B: Trapping Period

Factor B: Trapping Period	Poor	Intermediate	Advanced
1	B B 0.89 B B	E E 0.72 E E	S S 2.56 S S
2	G G 0.95 G G	K K 0.89 K K	R R 2.50 R R
3	F F 1.98 F F	P P 1.00 P P	Z Z 1.85 Z Z
4	N N 0.46 N N	M M 1.19 M M	Y Y 1.56 Y Y

Fig. 3. Trapping success (captures per 100 trap-nights) for 12 study mines for the genus *Peromyscus* depicting a two-way, fixed effects, one observation per cell analysis-of-variance design.

Table 3. Results of two-way analysis-of-variance on trapping success for the genus *Peromyscus* for the 12 study mines with revegetation category and trapping period as factors.

Source of variation	Degrees of freedom	Mean square	F value
Revegetation category	2	1.65	6.11*
Trapping period	3	0.16	0.59
Interaction	6	0.27	--

* Significant at $p = 0.05$

trapping periods. As a result of this test, the four trapping periods were combined in all succeeding analyses. A least significant range test (LSR) (Sokal and Rohlf 1969) revealed that the mines in the advanced revegetation category had significantly greater trapping successes than the mines in the intermediate revegetation category ($p = 0.05$). Mines in the advanced revegetation category also had significantly greater trapping successes than the mines in the poor revegetation category, but only at the 10 percent probability level. No significant differences were observed between the mines in the intermediate revegetation category and the mines in the poor revegetation category.

Trapping success was calculated for each vegetation unit where Peromyscus was captured. Correlation and multiple regression techniques were employed to determine significant relationships between trapping success and the habitat variables measured in the study. Trapping success served as the dependent variable in the regression models.

Pearson correlation coefficients were calculated between trapping success and all the habitat variables. Correlation coefficients were all low, however several relationships between trapping success and particular habitat variables were significant ($p = 0.10$), or nearly so ($p = 0.15$). These relationships are summarized in Table 4.

Multiple regression models were initially developed utilizing all the habitat variables as possible independent variables. Significant relationships ($p = 0.05$) were observed in these models between certain surface or deep soil variables and trapping success. In several cases, however, a particular surface variable showed a significant positive

Table 4. Summary of the most significant relationships between trapping success and particular habitat variables as revealed by Pearson correlation coefficients (r).

Variable correlated with trapping success	r
DK	0.383*
WSD	0.332*
WVHD	0.328*
WS4	0.294**
V2	0.290**
VT	0.285**

* Significant at $p = 0.10$

** Significant at $p = 0.15$

or negative relationship and the corresponding deep variable showed a significant relationship opposite in sign to the relationship exhibited by its surface partner. This was inconsistent with the findings of Haufler (1976) that corresponding surface and deep soil variables were highly correlated and possessed similar group means. All soil variables were dropped from succeeding regression models because of this inconsistency.

Subsequent regression models revealed that the variable most closely associated with trapping success was NT (the number of traps in each vegetation unit), a relative indicator of area. A highly significant ($p = 0.001$) inverse relationship was observed between trapping success and NT. The linear regression model corresponding to this relationship was

$$\text{Trapping success} = 3.415 - 0.036\ (NT).$$

The coefficient of determination (R^2) for this one-variable model was quite low ($R^2 = 0.22$), indicating that NT accounted for only about a fifth of the total variation in trapping success. A plot of NT versus trapping success is shown in Fig. 4. It can be seen from Fig. 4 that the relationship between NT and trapping success is not a linear one as the regression model implies, but appears to be an exponential function of the form

$$\text{Trapping success} = -ae^{b\ (NT)}$$

where e is the base of the natural logarithm and a and b are constants.

Two hypotheses were proposed to explain the relationship between area and trapping success:

1. The relationship was a function of the habitat.

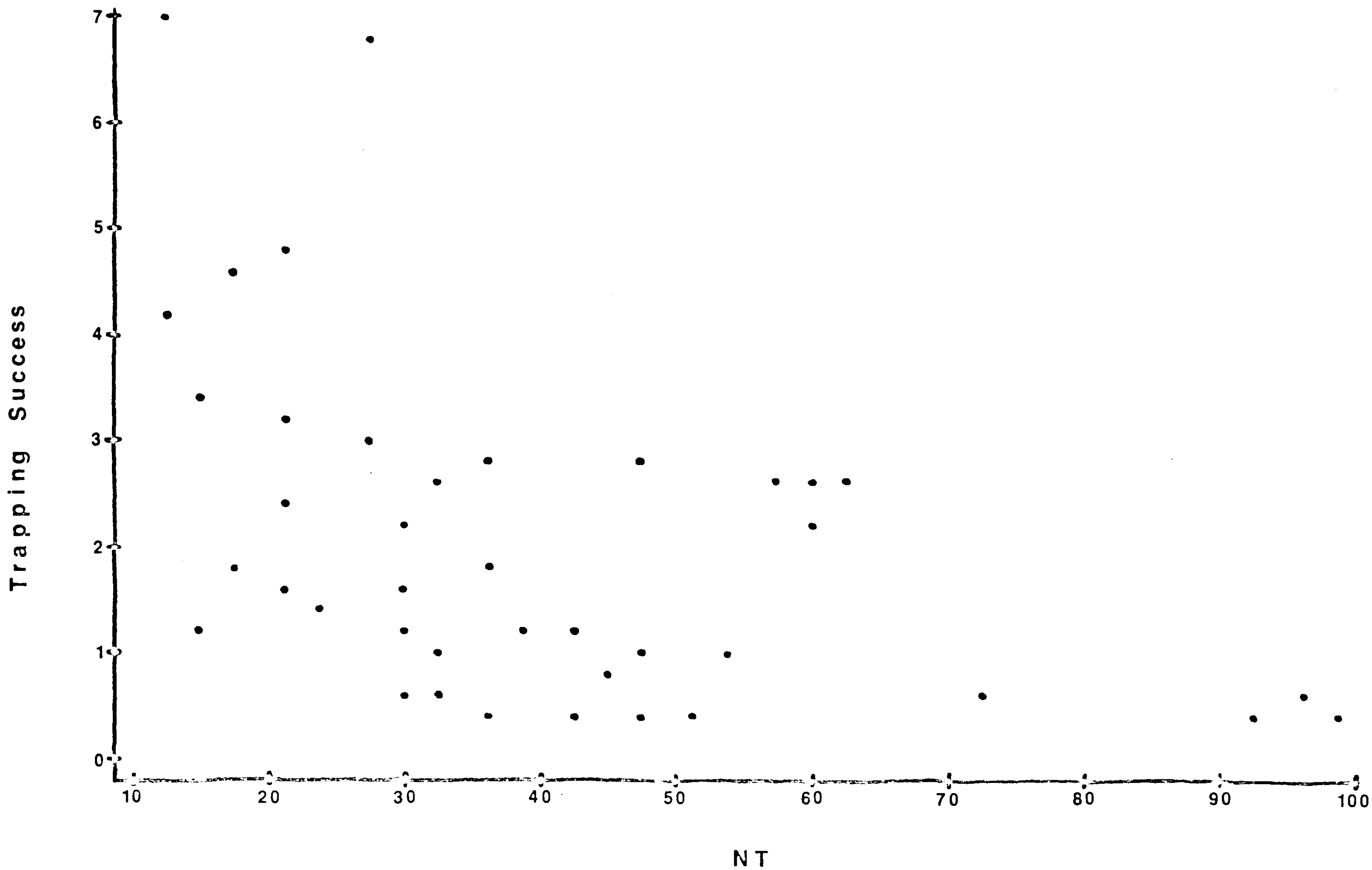

Fig. 4. Graph depicting relationship between NT (traps per vegetation unit) and trapping success (captures per 100 trap-nights) for the genus _Peromyscus_ on the 12 study mines.

Smaller vegetation units have a greater proportion of edge in relation to their area than larger units. This edge effect may have led to larger population densities in the smaller units by way of enhancing the interspersion and juxtaposition of habitat components important to Peromyscus populations.

2. The relationship was a function of the trapping methods employed. A purely mathematical relationship between area and trapping success may have come into play because of the way the traps were spaced.

If the second hypothesis was true, then an attempt would have to be made to eliminate the bias in trapping success caused by the trapping methods.

Mathematical modelling provided evidence which tended to support the second hypothesis. It was shown, for a fixed population density and trap station spacing, that an inverse relationship exists between area and trapping success as long as the trapping stations are close enough together to compete with each other for the animals present on the area. Whether or not the trapping stations are close enough to foster competition depends upon the movement patterns and home range of the species in question. The smaller the home range, the closer together trapping stations can be located without the effect of overlapping areas of influence, and hence trap competition coming into play. A graph of the relationship between area and trapping success under conditions where trap competition exists is shown in Fig. 5. This graph was constructed assuming a fixed population

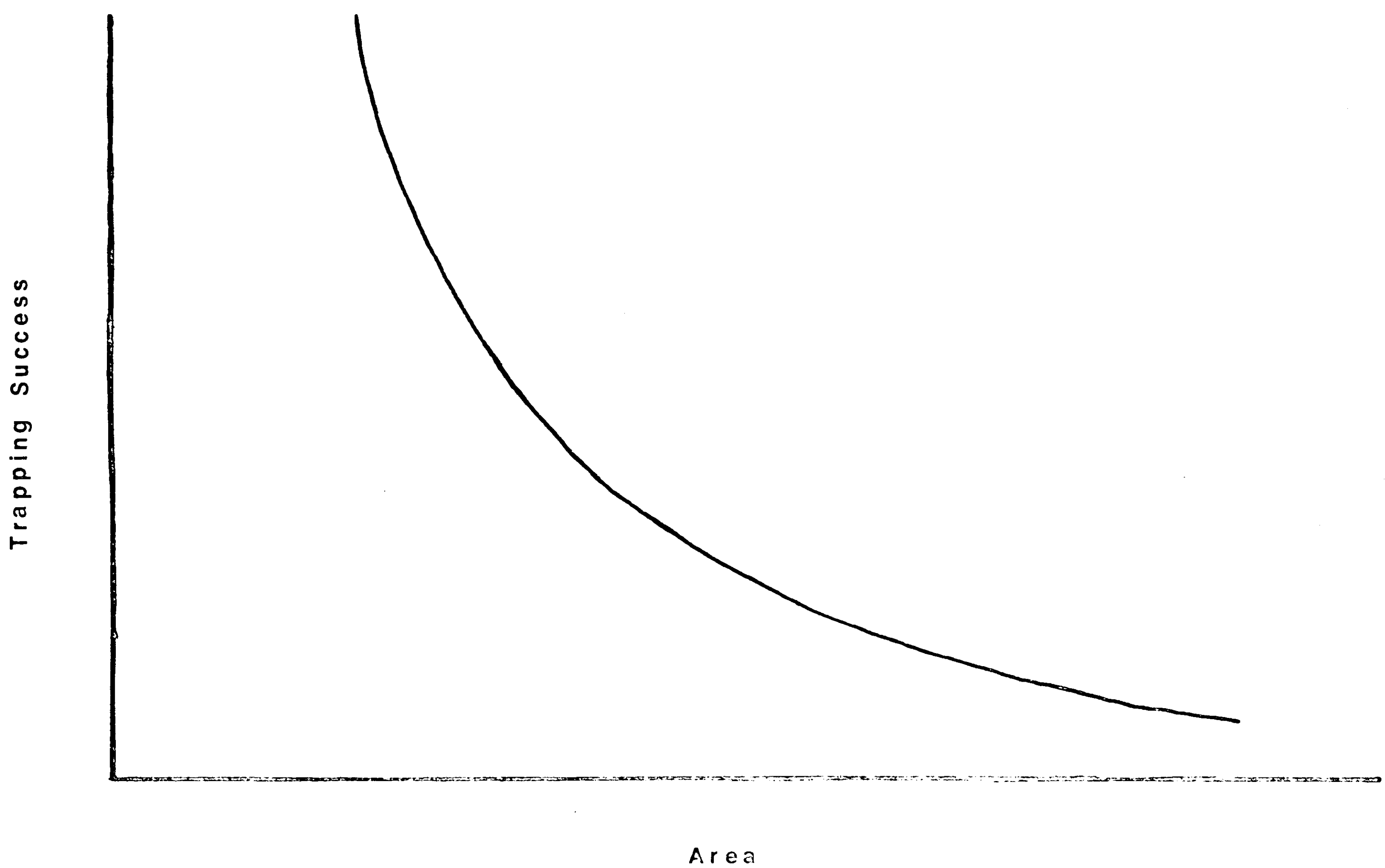

Fig. 5. Graph depicting relationship between area of unit trapped and trapping success when population density is fixed, trap station spacing is fixed, and the areas of influence of the trapping stations are circular and overlap by half a radius.

density and circular areas of influence around the trapping stations. Trapping stations were assumed to be spaced such that their areas of influence overlapped to the extent of half their radii. The relationship displayed in Fig. 5 is that of an exponential function and is very similar to the relationship between NT and trapping success actually observed in the study (Fig. 4).

In order to remove the apparent bias introduced into the regression models by the trap spacing, only vegetation units containing 30 or more traps were included in subsequent regression models. This eliminated the smaller units where the apparent effects of area on trapping success were most pronounced. After these units were eliminated, NT failed to appear in the regression models as an important variable.

Final multiple regression analyses revealed that the variable with the best relationship to trapping success was WS4, the stem density of trees greater than 7.6 cm DBH. The regression model corresponding to this relationship was

$$\text{Trapping Success} = 1.035 + 0.091\ (\text{WS4}).$$

The R^2 for this model was 0.23, indicating that WS4 accounted for slightly less than a fourth of the total variation in trapping success, and the relationship was significant at the 0.05 probability level. This model indicates a weak, but direct relationship between trapping success and the stem density of large trees. Extending the regression model to include more than one independent variable proved to be a fruitless endeavor since relationships between additional variables and trapping success were either insignificant or nonsensical.

The variables discussed above were associated only with *Peromyscus* abundance. It is possible that quite different variables may have been involved in determining the presence or absence of mice, irrespective of their abundance. In order to determine which variables were associated with the presence or absence of *Peromyscus*, the vegetation units were divided into two groups: units where mice were captured and units where no mice were captured. A t-test was then performed for each habitat variable to detect significant differences between the means of the two groups. The two groups were treated as independent samples in the calculation of the t-statistics. An F-test was also performed for each variable to determine if the group variances were equal. Depending on the results of the F test, the appropriate t-statistic was calculated. The results of these tests are presented for each variable in Table 5. Also included in Table 5 are the mean, standard deviation and number of vegetation units for each group.

Table 5. Results of t-tests for all habitat variables comparing vegetation units where Peromyscus was captured with units where Peromyscus was not captured.

Variable	Group	Number of vegetation units	Mean	Standard deviation	Variances	t value
TC	1[+]	36	0.54	0.40	Unequal	-3.41*
	2[++]	62	0.80	0.30		
HC	1	36	0.29	0.33	Equal	-2.05*
	2	62	0.43	0.34		
WC	1	36	0.34	0.37	Equal	-3.11*
	2	62	0.59	0.39		
WSO	1	36	46.94	56.37	Equal	-1.68
	2	62	68.97	66.12		
WS1	1	36	11.50	17.20	Unequal	-1.94
	2	62	21.55	33.86		
WS2	1	36	7.83	15.68	Unequal	-0.60
	2	62	9.58	10.35		
WS3	1	36	4.61	8.47	Unequal	-1.44
	2	62	7.76	13.07		
WS4	1	36	2.69	5.77	Equal	-0.92
	2	62	3.79	5.68		
WST	1	36	73.58	83.51	Equal	-2.02*
	2	62	111.65	93.33		
WSD	1	36	0.29	0.24	Equal	-1.67
	2	62	0.36	0.19		
WWSD	1	36	29.20	42.96	Equal	-1.70
	2	62	43.69	39.11		
VO	1	36	0.27	0.27	Equal	-2.77*
	2	62	0.44	0.28		
V1	1	36	0.48	0.70	Equal	-2.10*
	2	62	0.80	0.75		
V2	1	36	0.68	1.61	Unequal	-3.07*
	2	62	2.38	3.81		
VT	1	36	1.43	2.29	Unequal	-3.34*
	2	62	3.62	4.18		
VHD	1	36	0.24	0.17	Unequal	-1.55
	2	62	0.29	0.12		
WVHD	1	36	0.50	0.78	Equal	-2.43*
	2	62	0.96	0.99		
ROCKS	1	36	1.28	1.55	Unequal	-1.33
	2	62	1.81	2.44		
NSPP	1	35	11.46	4.95	Equal	-2.82*
	2	57	14.79	5.82		
SPH	1	34	4.45	0.67	Equal	-3.68*
	2	57	5.02	0.75		

Table 5. Results of t-tests for all habitat variables comparing vegetation units where Peromyscus was captured with units where Peromyscus was not captured (continued).

Variable	Group	Number of vegetation units	Mean	Standard deviation	Variances	t value
SCA	1	34	148.18	174.27	Unequal	-5.29*
	2	57	412.37	302.17		
SMG	1	34	66.85	46.90	Unequal	-2.99*
	2	57	94.40	34.04		
SPO	1	34	5.23	9.14	Unequal	-4.04*
	2	57	15.74	15.70		
SK	1	34	38.29	17.98	Equal	-3.95*
	2	57	57.25	24.30		
SSALT	1	34	96.32	133.48	Equal	0.27
	2	57	87.39	162.66		
DPH	1	33	4.40	0.73	Equal	-3.57*
	2	57	5.02	0.83		
DCA	1	33	111.12	116.58	Unequal	-4.71*
	2	57	314.70	288.26		
DMG	1	33	65.61	45.97	Unequal	-2.45*
	2	57	88.09	33.72		
DPO	1	33	4.70	8.72	Unequal	-3.84*
	2	57	15.53	17.93		
DK	1	33	32.82	14.74	Equal	-3.43*
	2	57	44.14	15.27		
DSALT	1	33	102.00	129.25	Equal	0.95
	2	57	74.79	132.30		

+ Units where no Peromyscus were captured
++ Units where Peromyscus were captured
* Significant at $p = 0.05$

DISCUSSION

Species Habitat Preferences

General

In reviewing the general habitat types in which species other than *Peromyscus* were captured, a definite trend is apparent. The majority of species were captured in areas in the middle to late successional stages. Areas that were bare, or dominated by herbaceous vegetation received little use by small mammals. The use of abandoned surface mine habitats in southwestern Virginia by small mammals thus appears to depend on at least the rudimentary development of the deciduous forest. This is not surprising, since the mammalian colonizers of these surface mine islands must come from the surrounding sea of deciduous forest and would be expected to utilize mine habitats most like their normal forest habitat.

The degree to which early successional stages on the mines are utilized depends upon the ecological plasticity of the various species of small mammals and the degree to which their normal habitat supplies their needs. Some species (eg. the cottontail) seem to have less specific habitat requirements than other species (eg. the flying squirrel) and can thus utilize the early successional stages to a greater degree. Use of these areas would tend to increase during years of high population density in relation to some essential ecological requirement (eg. food, nest cavities) when there would be ecological pressure to utilize new, previously unused areas.

One limitation of the results should be apparent, namely that they represent mammalian use of abandoned surface mines during only one season of one year. Habitat use throughout the course of a year may vary considerably with the seasons. Year-around habitat use should be documented if the true importance of the abandoned surface mine habitats to small mammal populations is to be determined. Due to the yearly fluctuations in small mammal numbers, several years data are also desirable.

It is felt that techniques other than trapping are needed to acquire data and render it comparable to data obtained from other seasons and other years. Trapping results from different seasons and different years may not be comparable for a particular species because of a variation in the species' trap response. The trap response of any species is dependent on a number of factors: bait acceptance, weather, movement patterns, and natural curiosity for strange objects, to name a few. In addition to weather, bait acceptance is known to vary seasonally (Fitch 1954). It is probable that the other factors also vary seasonally and possibly even yearly. Thus trap response can not be expected to remain constant and data from different seasons and different years are not necessarily comparable.

The likelihood of a species-specific trap response is also the reason why the species captured were not compared in terms of relative abundance. Small differences in numbers captured between two species may simply have been a reflection of a difference in trapability between the two species rather than an indication of relative population sizes. The gross comparison of relative abundance getween the genus Peromyscus and the other species captured is felt to be justified because of the extremely large numbers of these mice captured relative to the other species. It is doubtful that such large differences in numbers captured would have arisen from differential trapability alone.

Mammalian species diversity is another important community parameter that was not adequately treated. There would have been no confidence associated with saying that a species was present in one area and not in another because in most cases only one or two individuals were captured in any one area. The failure of an area to yield one or two animals of a particular species to the traps was very likely a result of chance, especially if the population density was low. Comparisons of diversity between habitats were therefore not attempted.

Peromyscus

Based on the results of the data analysis, it is concluded that Peromyscus abundance, as represented by trapping success, is positively associated with the reestablishment of deciduous forest on the abandoned surface mines. The analysis-of-variance test supports this conclusion by showing that mice of this genus were significantly more abundant on reforested mines than on either bare or predominantly herbaceous mines. The correlation tests similarly support this conclusion by demonstrating positive relationships between trapping success and DK (deep soil potassium), WSD (woody stem size diversity), WVHD (weighted vegetation volume height diversity), WS4 (woody stem density greater than 7.6 cm DBH), V2 (vegetation volume greater than 4 m in height), and VT (total vegetation volume).

Haufler (1976) found that soil potassium levels were directly related to the degree of reforestation on the mines, and it is readily apparent that the other variables correlated with trapping success are also directly related to the degree of reforestation. Finally, supporting evidence for the conclusion comes from the regression model demonstrating a positive relationship between trapping success and WS4.

The above conclusion can be carried a step farther, in light of the correlation test results, by adding that *Peromyscus* abundance is greatest in areas characterized by a diverse vegetative profile. Trapping success was correlated with two variables, namely WSD and WVHD, which were indicative not only of the degree of reforestation, but also of the degree of vegetative layering. It might at first seem incongruous that forested areas on the mines also displayed the greatest vegetative layering, however the forests on these mines were no more than 26 years old, and hence were not mature enough to exhibit the sparse herbaceous and shrubby understories characteristic of climax forests.

Several assumptions were necessary to facilitate the use of trapping success as an index of abundance for *Peromyscus*. The major assumption was that the traps captured mice in relative proportion to their true abundance. Implicit in this assumption was the supposition that the trap response of the genus *Peromyscus* was identical on all the mines trapped during a particular trapping period and was independent of habitat type. These assumptions are tenuous at best and their failure to hold up may have been one reason for the low correlation coefficients and regression coefficients of determination observed in the relationships between trapping success and the habitat variables. It was initially assumed that trapping success was also independent of area as long as the spacing between trapping stations was kept constant. It was felt that if trap spacing was kept constant, trap density would likewise have been constant. This assumption was shown to be false when the trapping stations are sufficiently close to result in overlapping areas of influence between adjacent trapping stations and hence competition between the trapping stations. As the area increases, the overlapping nature of the trapping stations effectively increases the density of traps, rendering the assumption of uniform trap density invalid and introducing a bias into the use of trapping success in comparisons of abundance between vegetation units of different size.

The effect of area on trapping success should be taken into account in all future studies where the intent is to use trapping success in comparisons of abundance between land tracts of different area. There are two ways to eliminate the bias from such a study. One way is to space the trapping stations far enough apart so that their areas of influence do not overlap. The spacing necessary to produce non-overlapping areas of influence varies with the species being trapped since it has already been noted that the area of influence of a trapping station depends on the movement patterns and home ramge of the species in question. One way to ensure the proper trap spacing is to try various spacing distances and observe at what distance the relationship between trapping success and area becomes a linear one with no slope. An alternative to this rather time consuming method is simply to space the traps at least as far apart as the diameter of the home range of the species in question (Hansson 1968). Varying the spacing of the trapping stations is a method of assuring non-competing areas of influence which is most easily and optimally applied when only one or two species are being considered simultaneously. A second way to eliminate the influence of area on trapping success is to take advantage of the exponential nature of the relationship between the two variables as was done in this study. The smaller sized tracts can simply be eliminated from the analysis, leaving the larger tracts where the relationship is insiginficant. This method is most useful in studies where several mammalian species are being considered and the trap station spacing can not be made optimal for all species simultaneously.

The results of the t-tests indicate that vegetation units where Peromyscus was captured had significantly greater vegetation development, as well as significantly higher soil pH and nutrient levels than units where Peromyscus was not captured. Thus the presence of these mice is related to the successful reestablishment of vegetation on the surface mines which, in turn, is dependent on the quality of the soil.

It is noteworthy that Peromyscus presence was related to total vegetative development rather than to only one or two vegetative parameters. Although maximum population densities are realized in the deciduous forest, members of this genus appear quite able to utilize any area with an adequate vegetative cover, regardless of the cover type. This ecological plasticity allows them to invade the abandoned surface mine habitats long before these habitats have become suitable for the majority of the other forest-dwelling species. These other species must wait until the abandoned mines have at least partially reforested before they can make appreciable use of the mines.

One difficulty encountered in this study was the inability to distinguish between the two subspecies of Peromyscus captured. Both the subspecies P. leucopus noveboracensis and P. maniculatus nubiterrae were captured on the study mines. A few specimens could be clearly identified as belonging to one or the other subspecies, however a large number of specimens were simply impossible to identify with any degree of certainty. The fact that these two particular sub-species are confusingly similar has been noted by Handley and Patton (1947). The morphological similarity between the two subspecies is undoubtedly due to the fact that they are both predominantly forest-dwelling forms and occupy similar ecological niches within their forest habitat. Where they occur together, the only difference in habitat preferences between the two subspecies appears to be that P. maniculatus nubiterrae prefers cooler, moister areas of the forest than does P. leucopus noveboracensis (Odum 1944). In the more northern forests of New England and Canada, P. maniculatus nubiterrae is replaced by P. m. gracilis which is its ecological equivalent (Kirkland and Linzey 1973). Morphological and ecological similarities between this subspecies of maniculatus and P. leucopus noveboracensis have been more extensively studied than those between P. maniculatus nubiterrae and P. leucopus noveboracensis. These studies have indicated that considerable morphological (Horner 1954) and ecological similarity exists between the two subspecies with the exception that *P. mariculatus gracillis* prefers cooler, moister areas of the forest than does *P. leucopus noveboracensis* (Klein 1960, Smith and Speller 1970). In view of the ecological similarity between forest subspecies of *P. maniculatus* and *P. leucopus noveboracensis*, the fact that the two subspecies of *Peromyscus* were indistinguishable appears to be of little consequence for the purposes of this study.

Past research by other workers on the genus *Peromyscus* has tended to corroborate the results obtained in this study. It has already been mentioned that both subspecies encountered in this study have been shown to be predominantly inhabitants of the deciduous forest. Additional studies on *P. leucopus noveboracensis* have indicated that members of this subspecies are capable of occupying a wide range of habitat types, but that they generally are most abundant in shrubby or forested areas (Beckwith 1954, Brown 1964, Jameson 1955, Pearson 1959). It has also been shown that, within the deciduous forest, *P. leucopus* is most abundant in areas with a well-developed herb and shrub understory (Bergner 1969, Getz 1961, M'Closkey 1975b, M'Closkey and Lajoie 1975, Stickel and Warbach 1960). M'Closkey (1975a) felt that the arboreal habit of this species was an important reason for their preference for areas with a diverse vegetative profile.

Abandoned Contour Surface Mines as Small Mammal Habitat

Based on the results of this study, it is concluded that abandoned contour surface mines in southwestern Virginia are not extensively utilized by the majority of small mammal species indigenous to the area until the mine habitats have revegetated sufficiently to resemble the natural forest vegetation of the area. Mines dominated by bare areas, or predominantly herbaceous vegetation are suitable for use by only a few mammalian species, the most notable of which belong to the genus Peromyscus. Even for those species which can utilize the early successional areas, the use of such areas is minor compared to the use of areas more closely resembling the deciduous forest. Herbaceous areas could conceivably be utilized by species more characteristic of early successional stages, such as the prairie deer mouse (Peromyscus maniculatus baiirdi) or the meadow vole (Microtus pennsylvanicus), however due to the vastness of the deciduous forest in this region of the country, there are few areas from which these species could emigrate.

The low mammalian use intensity of the early successional stages observed in this study appears to conflict with what has been found by other researchers studying mammalian use of surface mines (Mumford and Bramble 1973, Jones 1967, Riley 1953, 1954, Sly 1976, Verts 1957, 1959, Wetzel 1958). The apparent conflict is resolved, however, when it is realized that these studies were all conducted in the Midwest on area surface mines. Species which were found to utilize appreciably the early successional stages on the area mines were characteristically inhabitants of the natural herbaceous habitats common throughout this region of the country. The only study, other than the current one, which examined small mammal populations on surface mines in a mountainous, forested region was the study conducted by Kirkland (1976). His results were consistent with the ones obtained in this study. It is felt that the mammalian use patterns documented in this study are valid for areas throughout the Appalachian region where similar vegetation, topography and mining methods predominante.

One aspect of the value of abandoned surface mines as small mammal habitat was not dealt with in this study, namely how the mine habitats compare to the surrounding undisturbed forest. It is felt that, with the possible exception of the genus Peromyscus, both small mammal abundance and diversity are lower on the mines than in the forest. Future study is needed to test the validity of this hypothesis.

The problem of seasonal differences in habitat use by small mammals has already been mentioned, but deserves repeating here. This study measured habitat use only during the summer months of June, July and August. This time of the year is the most favorable for small mammals in terms of the availability of food and cover. Although forested areas are used more extensively than herbaceous areas at this time of year on the surface mines, it is conceivable that use patterns could reverse during the winter when conditions in the forest are not as favorable, particularly in terms of food availability. During the winter, herbaceous areas may be more attractive than at other times of the year because of the large quantity of seeds normally present in these areas. These seeds would provide a welcome food supply for small mammals, particularly for species such as Peromyscus leucopus and P. maniculatus which are extremely opportunistic in their food habits (Hamilton 1941). The use of herbaceous areas during the winter by P. leucopus has been documented by Getz (1961). He found that P. leucopus normally inhabited wooded areas, but that they moved into herbaceous areas during the winter. The mice were found to be utilizing the seeds of forbs present in these herbaceous areas as a food supply. Similar seasonal use of herbaceous areas by the genus Peromyscus was suggested in this study by results obtained during trapping conducted in early March, 1977. This trapping was conducted primarily to obtain Peromyscus specimens for species identification purposes. During this trapping period, extremely large numbers of mice were captured in large herbaceous areas dominated by the forb sericea lespedeza (Lespedeza sericea). Extensive use of such areas had not been observed during the trapping conducted the previous summer. It is possible then, that early successional stages on abandoned surface mines, while not providing preferred habitat for most species of forest-dwelling small mammals, do serve an important function by providing much needed food during critical times of the year. The value of these habitats to the small mammals may thus have been underestimated in this study.

The abundance and ubiquity of the genus Peromyscus on abandoned contour surface mines may be important from several standpoints. These mice may be an important food item, at least seasonally, in the diets of larger mammals and birds. Fox sign was observed on nearly every mine during the study and several gray foxes (Urocyon cinereoargenteus) were sighted on the mines. Conversations with landowners in the vicinity of the mines indicated that gray foxes were abundant throughout the study area. Use of the mines by raptors was also apparent as they were often observed soaring over the mines. Rodents are important food items in the diets of these animals, however, additional study is needed to determine the degree of utilization of *Peromyscus* as a food item by these animals. In addition to their possible significance as a food source for other animals, *Peromyscus* populations may be useful to man as a minimum indicator of wildlife habitat quality on abandoned surface mines. Mine habitats unsuitable for use by these mice due to poor soil quality and inadequate vegetation development are undoubtedly a long way from being suitable habitat for other, less ecologically tolerant mammals. Conversely, areas meeting some predetermined minimum use level by this genus would be on their way toward ecological recovery and probably would not be deserving of additional habitat improvement. Habitat use by *Peromyscus* may thus be of value as a criterion in the evaluation of wildlife-oriented reclamation work on abandoned surface mines.

SUMMARY AND CONCLUSIONS

Eleven species of mammals were captured during the study. White-footed mice (Peromyscus leucopus noveboracensis) and deer mice (P. maniculatus nubiterrae) were the only small mammals captured in large numbers and in a wide variety of habitat types on the abandoned surface mines. The majority of species were captured in areas that were in or approaching a forested condition. Use of the mines by most species, therefore, was not appreciable until the mines had at least partially reforested.

An analysis-of-variance test indicated that trapping success for the genus Peromyscus was greater in forested mine habitats than in either bare or predominantly herbaceous habitats.

Correlation tests revealed weak, but significant ($p = 0.10$) positive relationships between trapping success for Peromyscus and the following variables: soil potassium levels, woody stem size diversity, and weighted vegetation volume height diversity. Less significant ($p = 0.15$) positive relationships were observed between trapping success and the following variables: woody stem density greater than 7.6 cm DBH, vegetation volume greater than 4 m in height, and total vegetation volume.

Regression analyses revealed a significant ($p = 0.05$) positive relationship between trapping success for Peromyscus and woody stem density greater than 7.6 cm DBH.

It was concluded from the above tests that maximum Peromyscus abundance on abandoned surface mines in southwestern Virginia occurs in reforested mine habitats possessing a diverse vegetative profile.

Although white-footed mice and deer mice do utilize predominantly herbaceous areas, the level of use is low compared to that for the deciduous forest.

With the help of t-tests, it was determined that areas where *Peromyscus* was captured had significantly greater vegetation development and significantly higher soil pH and nutrient levels than areas where these mice were not captured.

Appreciable use of abandoned contour surface mines in southwestern Virginia by small mammals does not occur until the mines have revegetated sufficiently to resemble the natural habitat of the surrounding area. This statement must be qualified, however, by noting that this study measured only summer use of the mine habitats. Herbaceous mine habitats may be more extensively utilized by small mammals, particularly white-footed mice and deer mice, during the winter when food supplies in the forest are not prodigious and an abundance of seeds serves to attract unusually large numbers of mice into the herbaceous habitats.

The abundance and wide distribution exhibited by white-footed mice and deer mice may be significant from at least two standpoints. The mice may be important components in the diets of larger mammals and birds and hence serve to attract additional animal species into the mine habitats. Concurrently, these mice may be useful to man as minimum indicators of wildlife habitat quality and therefore serve as a useful criterion in the evaluation of wildlife-oriented surface mine reclamation work.

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SMALL MAMMAL USE OF ABANDONED SURFACE MINES IN SOUTHWESTERN VIRGINIA

by

William C. Flick

(ABSTRACT)

Trapping was conducted on 12 abandoned contour surface mines in southwestern Virginia during the summer of 1976 to determine relationships between small mammal diversity and abundance and select vegetation and site factors. Eleven species of mammals were captured during four, six-night trapping periods. Peromyscus leucopus novebcracensis and P. maniculatus nubiterrae were the most abundant and widespread mammals encountered on the mines. Other mammalian species were captured infrequently. General habitat types were noted where species other than Peromyscus were most frequently captured. Reforested mine habitats were utilized most heavily by small mammals. Herbaceous areas received little use during the summer, but may be more extensively utilized during the winter when food supplies in the forest are low. Peromyscus abundance, as measured by trapping success, was positively associated with the development of forested habitats possessing a diverse vegetative profile on the mines. Areas where Peromyscus was captured had significantly greater vegetation development and significantly higher soil pH and nutrient levels than areas where these mice were not captured. Peromyscus populations on the mines may be an important source of food for larger mammals and

birds. These mice may also be useful as minimum indicators of wildlife habitat quality and hence serve as a criterion in the evaluation of wildlife-oriented surface mine reclamation work.