BREEDING BIRD POPULATIONS IN RELATION TO THE VEGETATION STRUCTURE OF ABANDONED CONTOUR MINES IN SOUTHWEST VIRGINIA

by

David Lyle Chapman

Thesis submitted to the Graduate Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
in
FISHERIES AND WILDLIFE SCIENCES

APPROVED:

B. S. McGinnes, Chairman

R. H. Giles, Jr.

A. R. Tipton

R. L. Downing

October, 1977
Blacksburg, Virginia 24061

ACKNOWLEDGEMENTS

I would like to thank sincerely my advisor, Dr. B. S. McGinnes and my committee members, Dr. R. H. Giles, Jr., Dr. A. R. Tipton, and Mr. Robert L. Downing for their guidance throughout the project and their assistance in the preparation of the thesis. I also appreciate the financial support provided by the Office of Biological Services, U. S. Fish and Wildlife Service.

I am deeply indebted to and for their assistance in the bird censusing. Their ornithological expertise proved invaluable. I also thank for his help with the vegetation sampling.

I gratefully acknowledge the advice offered by and during the planning stages of this project. Special thanks are due to for her assistance in the statistical analyses and interpretation of the results.

I thank the Clinchfield Coal Co. and the Harman Mining Co. for allowing the use of their properties and for their help in locating the study areas.

I wish to thank my parents, Mr. and Mrs. , for their constant support and encouragement.

Finally, I would like to thank my wife, , for her devotion and understanding during the many months required to complete this study, and for typing the thesis.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

Surface mining of coal in Virginia began in 1940 with an annual production of 6,400 tons (U. S. Bureau of mines 1943). Technological advances stimulated rapid growth of the surface mining industry following World War II. Virginia's annual production increased from 656,000 tons in 1946 to 3.6 million tons in 1966 and 7.9 million tons in 1974 (U. S. Bureau of Mines 1949, 1967, 1975 respectively). However, as the new industry grew, so did the environmental impacts of surface mining.

Surface mining has been restricted to southwestern Virginia in Lee, Wise, Dickenson, Buchanan, Scott, Russell, and Tazewell Counties where coal seams are horizontally oriented. Because of the mountainous terrain of this area, the predominant method of surface mining is contour mining. This involves mining in relatively narrow strips, following the outcropping coal seam along the mountainsides. To expose the coal for extraction, overburden materials are removed and pushed over the side of the mountain, forming an outslope. A vertical highwall and a horizontal bench remain after coal removal (Fig. 1).

Prior to 1966, Virginia had no legal provisions which required surface mine operators to reclaim disturbed areas after mining. As a result, most of these areas were simply abandoned, hence they were called "orphan mines". In 1966, legislation was enacted which required the reclamation of

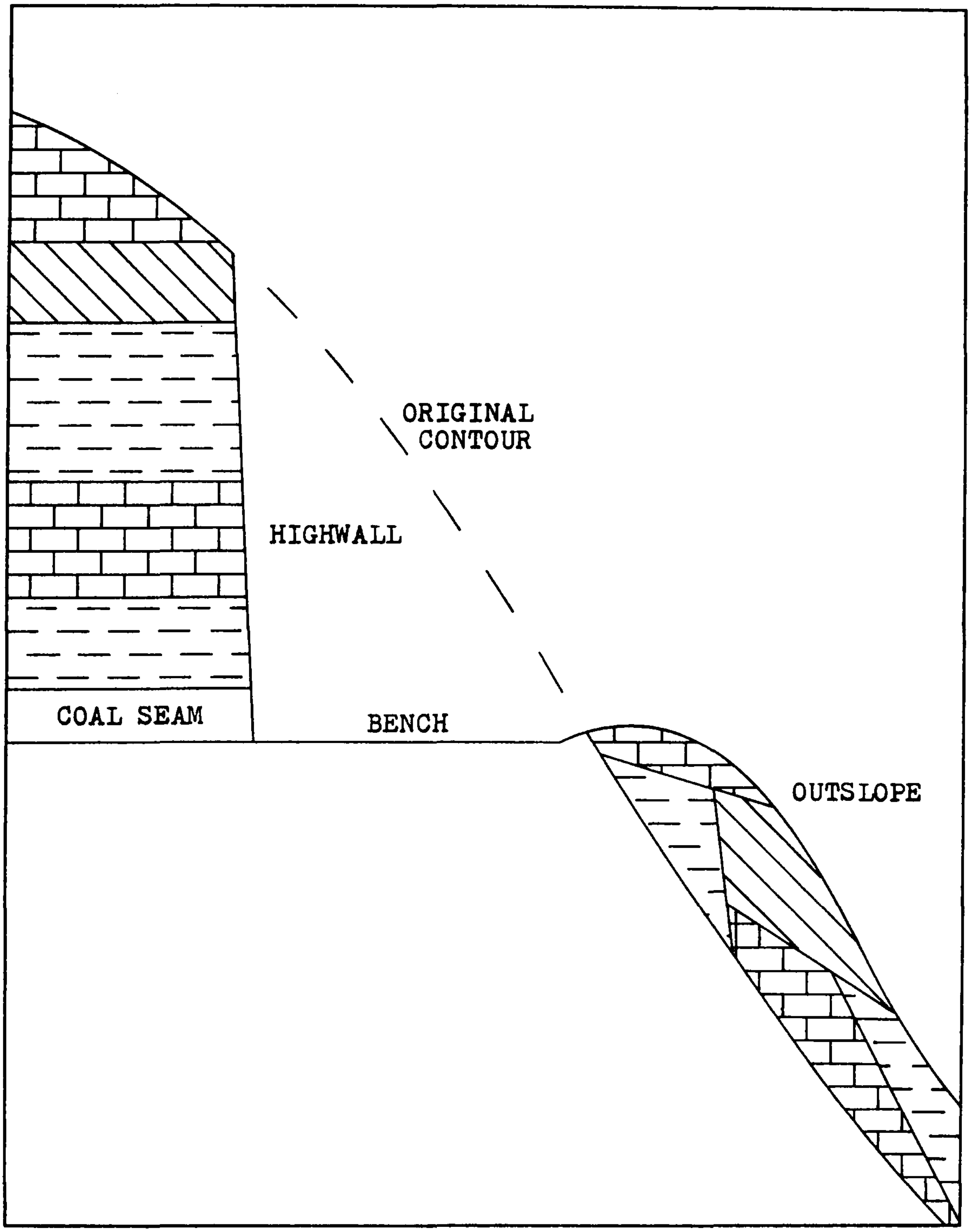

Fig. 1. Cross-sectional view of a typical contour surface mine.

all areas disturbed by surface mining (Code of Virginia of 1950, Title 45.1, Chapter 16, as amended. Effective June 27, 1966). However, no provisions were included in the new law to deal effectively with orphan mines.

The environmental impacts of orphan mines are numerous and far reaching. In many areas, acidic and nutrient deficient spoil materials have delayed or prevented natural revegetation, leading to extensive erosion and stream siltation. Exposed strata and spoil materials containing acid producing compounds contribute to stream pollution and adverse fisheries impacts. Sparsely vegetated orphan mines constitute relatively poor wildlife habitat and persistent highwalls may act as barriers to many wildlife species (Boccardy and Spaulding 1968). Aesthetics and property values may also be adversely effected.

Before Virginia's 1966 reclamation law came into effect, approximately 24,000 acres had been disturbed by surface coal mining in six counties within the Tennessee River Valley (Lee, Wise, Dickenson, Scott, Russell, and Tazewell Counties). Natural revegetation and remining, with subsequent required reclamation, has reduced the area of orphan mine land in need of reclamation to 19,000 acres within these counties (TVA [1975]). Additional orphan mine lands exist in Buchanan County where much surface mining was practiced before Virginia's 1966 reclamation law. The Tennessee Valley Authority has undertaken a project to reclaim orphan mines within its jurisdiction (TVA [1975]). Among the objectives of the project are improving wildlife habitat and alleviating offsite problems caused by these mines. The recently passed Surface Mining Control and Reclamation Act of 1977 will deal with abandoned surface mines on a national level.

In Virginia, orphan mines exhibit vegetative conditions ranging from completely bare ground to dense young forest. These extremes, and gradations in between, are often encountered within the boundaries of a single mine. The degree of revegetation on a mine, or a section of it, may not in itself indicate the need for reclamation. For example, a large bare area on the bench of a mine may have a negligible impact on the watershed below compared to an area of equal size lacking vegetation on the outslope. The impacts of either of these areas would be further affected by such factors as the distance to the nearest stream and the type and amount of vegetation existing within that distance. Also, the redisturbance of relatively well vegetated areas in gaining access to problem sites may offset the value of that reclamation. The actual need for reclamation may also be affected by the location of orphan mines relative to streams and residences. Landowner objectives, cost-benefit ratios, and wildlife values further complicate the reclamation decision. Thus, there is clearly the need for an aid to reclamation decision-making capable of integrating these and many other factors.

At Virginia Polytechnic Institute and State University, a computer-based decision aiding system is being developed for use in selecting optimum orphan mine reclamation strategies. Wildlife utilization before and after reclamation will be important considerations in this system. However, very little information is currently available pertaining to the use by wildlife of this type of disturbed area. This study investigates the breeding bird utilization of orphan contour mines. More specifically, this is an attempt to relate breeding bird population parameters to the vegetational development of abandoned contour mines in Virginia. The primary objectives of this research were to determine the structural features of the vegetative substrate which have the greatest affect on breeding bird populations and to develop mathematical equations which would permit population parameters to be predicted from these structural features. Achievement of these objectives might provide a basis for evaluating orphan mines as breeding bird habitats.

LITERATURE REVIEW

A commonly used index of avian diversity is the bird species diversity index (BSD) which is calculated using the Shannon formula (Shannon and Weaver 1949):

$$BSD = H' = -\sum_{i=1}^{n} P_i \, Log_e \, P_i$$

where n = the total number of species.

P_i = the proportion of the total number of breeding pairs contributed by pairs of species i.

This formula accounts for both the total number of species (species richness) and the relative abundance of each species (species equitability). Thus, the value of BSD will increase as the number of species increases and as the numbers of pairs become more equally distributed among species.

The relationships between avian diversity and vegetation structure were initially investigated by MacArthur and MacArthur (1961) in eastern deciduous forests. A positive linear correlation was found between BSD and a foliage height diversity index (FHD). The FHD index was also based on the Shannon formula:

$$FHD = H' = -\sum_{i=1}^{n} P_i \, Log_e \, P_i$$

where n = the number of defined foliage layers.

P_i = the proportion of the total foliage which occurs in layer i.

This index is an expression of the complexity of the foliage profile. The value of FHD will increase as the number of foliage layers increases and as the amounts of foliage become more equally distributed within the layers. Foliage was stratified into layers of less than 0.6m, 0.6-7.6m, and greater than 7.6m in height. MacArthur and MacArthur (1961) also found plant species diversity (Shannon formula) to be good predictor of BSD. However, they concluded that plant species diversity increased with the complexity of the foliage profile and when this relationship was accounted for, FHD was in fact the better predictor of BSD.

In brushy fields and other early stages of forest succession in Pennsylvania and Vermont, MacArthur et al. (1962) found that in many cases the presence of a species could be predicted from measurements of foliage profile using strata heights of less than 0.6m, 0.6-4.6m, and greater than 4.6m. The abundance of a species was related to the number of patches of vegetation which had a foliage profile acceptable to that species. They concluded that avian diversity was primarily determined by the horizontal variability in foliage profiles within a habitat, however, no attempt was made to demonstrate statistically this relationship.

In Arizona, MacArthur (1964) found FHD to be a good predictor of BSD for a variety of habitats ranging from semi-desert to forest. He pointed out, however, that FHD was useful only within homogeneous habitats. In ecotones or other habitats with great internal variation in foliage profile, BSD could not be predicted by FHD.

In Illinois, Karr (1968) investigated breeding bird populations in relation to the vegetation structure of four area-type coal mines in different successional stages. A significant linear correlation was found between BSD and FHD (using foliage layers of less than 0.6m, 0.6-6.1m, and greater than 6.1m). A linear relationship was also found between BSD and the logarithm of percent vegetation cover (PCVC) which was determined by summing the estimates of percent cover for the three strata. This index emphasized the horizontal extent of the vegetation layers, whereas FHD emphasized vertical distribution. Karr realized that his study areas were quite heterogeneous. However, he felt that the distribution and intergradation of habitat types was relatively uniform within each study area.

A linear relationship of BSD to FHD has been found in a variety of habitat types in Texas and Panama (Karr and Roth 1971), in Puerto Rico (MacArthur et al. 1966), and in Australia (Recher 1969). Bird species diversity has also been found to be sigmoidally related to PCVC in

Illinois, Panama, and Texas (Karr and Roth 1971).

Willson (1974) found a linear correlation between BSD and FHD for 21 study areas in Illinois habitats ranging from grassland to forest. Willson noted that while an overall correlation was evident, FHD failed to predict BSD for a subset of eight woodland areas. A curvilinear relationship was found for all 21 areas between BSD and PCVC, however, no significant relationship was found for the eight woodland areas alone. These results did not concur with those of many earlier studies and prompted Willson to question the biological justification for using FHD to predict BSD.

Roth (1976) developed an index of spatial heterogeneity in an attempt to find a correlate for BSD in habitats where a BSD-FHD or BSD-PCVC relationship could not be demonstrated. The index, called the Coefficient of Variation of Distance (D), was calculated from the distances to a nearest plant form (shrub or tree) from a series of sample points:

$$D = 100(sd)/\bar{x}$$

where $\bar{x}$ = the mean of the point-to-plant distances.

sd = the standard deviation of the point-to-plant distances.

The habitats studied included four Texas brush-grasslands, two Illinois shrub communities (early shrub and late shrub-tree stages), and four Delaware forest communities. The index showed a linear relationship with BSD when point-to-shrub distances were used (D_s). More important, however, was the fact that BSD was linearly related to D_s for the Texas communities where previously a BSD-FHD relationship could not be demonstrated. Roth maintained that FHD (as well as PCVC) was only a coarse predictor of BSD, and that the BSD-FHD relationship could only be demonstrated over a wide range of habitat types. Within geographically and structurally similar habitats, differences in BSD were due to subtle variations in vegetation structure which FHD could not detect. This would seem to explain Willson's (1974) findings. Roth noted, however, that his heterogeneity index was not a good predictor of BSD in forest habitats and that the need remained for an index of habitat structure which could accurately predict BSD over a range of habitat types and also within structurally similar habitats.

The studies thus far reviewed have demonstrated statistically the importance of vegetative structural complexity (both horizontally and vertically) as a determinant of avian breeding diversity. A number of studies, though not specifically designed to investigate relationships between populations and vegetation structure, have reported general trends which tend to support these findings.

Hereafter, the term diversity will refer to the number of species (species richness).

In general, as ecological succession proceeds from bare ground to climax forest, the structural complexity of the plant community increases as new layers of foliage are added. Several studies have demonstrated that breeding bird populations tend to increase with ecological succession. In the Piedmont region of Georgia, Johnston and Odum (1956) studied the breeding bird populations of ten plant communities representative of successive seres from abandoned field to climax forest. Both density and diversity showed positive relationships with the ecological age of the study areas. Shugart and James (1973) also reported a positive trend between breeding bird density and the ecological age of their study areas in Arkansas. Conner and Adkisson (1975) observed progressively higher numbers of species in 1, 3, 7, and 12-year-old forest clearcuts in Virginia.

Several studies have reported increases in breeding bird populations of various habitats as a result of increased structural complexity. Monson (1941) compared bird populations of controlled and uncontrolled grazing areas in Arizona. An increase in vegetation cover and volume in the controlled area resulted in higher bird diversity and density than was observed in the uncontrolled area. In Ohio, Dambach (1944) found that an ungrazed woodlot supported a more dense and diverse avian population than a grazed woodlot. Hooper (1967) found that diversity and density increased as shrub cover increased in young forests near clearcuts in Virginia. In Tennessee Ambrose (1975) found higher densities and diversities in two forests with well developed understories than were observed in a nearby forest with a sparse understory. Conner and Adkisson (1975) reported that the breeding bird population of a 30-year-old pole stand with a sparse understory was less dense and diverse than the populations of younger clearcuts with denser undergrowth. The value of understory development has also been demonstrated by Odum (1950) and Hooper et al. (1973).

To date, only two breeding bird studies are known to have been conducted on contour mines. Although these were not designed to relate the observed breeding bird populations to elements of vegetation structure, a few trends were reported. Yahner (1973) conducted breeding bird censuses in 1972 and 1973 on a Tennessee contour mine which had been mined in 1953 and reclaimed in 1955. Within the disturbed area, the highest number of species (32 for both years combined) was observed on the spoil (outslope) area which had a well developed shrub layer and scattered large trees. A much lower number of breeding species (18 for both years combined) was observed on the strip mined (bench) area which supported very few shrubs and no trees.

Garton (1974) surveyed a 3-year-old Tennessee contour mine and compared his results to those of Yahner (1973). Garton noted that the major difference in the populations of the two study areas occurred in the spoils areas. Garton's spoils area lacked the shrub and tree cover of Yahner's and supported fewer breeding species (22).

In summary, past research has shown that various parameters of breeding bird populations tend to increase as vegetative substrates become more structurally complex. Several studies have demonstrated BSD-FHD and/or BSD-PCVC relationships when bird populations of a variety of habitats were considered. Other studies have shown that bird populations tend to increase with ecological succession or other habitat changes which affect an increase in structural complexity. However, most past research has investigated breeding bird populations of homogeneous plant communities. It is not known if the results of these studies can be applied to abandoned contour mines which often exhibit a mosaic of vegetative cover types.

MATERIALS AND METHODS

Description of the General Study Area

The study was conducted in southwest Virginia in Wise, Dickenson, and Buchanan Counties. These counties lie within the Cumberland Plateau geomorphic province which has been described by Dietrich (1970) as a highly dissected plateau having a mountainous appearance. Elevations range from approximately 1500 to 3000 feet (457 to 914m). Most soils are derived from sandstone, shale, and coal and the dominant soil type is Muskingum (Wingo 1949). The bedrock is composed of relatively flat-lying sedimentary strata of Mississippian and Pennsylvanian age (Dietrich 1970). Average annual precipitation for this region is 44 inches (112cm) (NOAA 1974). Actual precipitation and average monthly temperatures recorded in the City of Wise, Wise County, Virginia for March-June, 1976 are presented in Table 1. Most of this region is drained by tributaries of the Tennessee River system (Dietrich 1970). The undisturbed vegetation is Mixed Mesophytic Forest and oaks are the dominant species (U.S.D.A. 1938).

Contour strip mining for coal has been practiced in this area since about 1940. The contour mines studied resulted from mining operations conducted on the Clintwood coal seam. The Clintwood is a relatively large seam yield-high grade coal and for this reason was one of the first seams to be mined. Orphan mines on the Clintwood seam vary

Table 1. Average temperature and total precipitation, by month, recorded in the City of Wise, Wise County, Virginia for March-June, 1976 (NOAA 1976).

Month	Average Temperature (°C)	Total Precipitation (cm)
March	9.6	13.79
April	12.2	2.54
May	14.9	7.57
June	20.2	8.13

in age from 11 to 30+ years and exhibit a wide range of vegetative conditions and wildlife habitats.

Selection of Individual Study Areas

Several study areas were needed to ensure sufficient representation of the range of vegetative conditions encountered on orphan contour mines. With this in mind, 12 study areas were selected, four in each of three vegetative classes representing what were subjectively considered to be low, intermediate, and high degrees of revegetation. Eleven of the areas were the same as those studied by Haufler (1976) in his investigation of critical factors affecting revegetation. The additional area selected had a high degree of revegetation and was located near the other three well vegetated sites.

The eight study areas with a low or intermediate degree of revegetation were located in Wise and Dickenson Counties approximately 0.5 to 5.0 miles (0.8 to 8.1km) southwest of Clintwood, Virginia. The elevation of these areas was approximately 1920 feet (585m). The four well vegetated areas were located in Buchanan County, approximately 1.5 to 2.0 miles (2.4 to 3.2km) south of Harman, Virginia at an elevation of about 2040 feet (622m). Within each area a section of disturbed land 200m long parallelling the highwall (variable in width from highwall to bottom of outslope) was delineated as the final study area.

Avifaunal Survey

Breeding bird censuses were conducted between 17 May and 26 June, 1976. The territorial mapping method (Williams 1936) was the basic census technique employed. Each study area was censused a total of six times. Of these, three were morning censuses conducted from approximately 0600 to 1000 EDT and three were evening censuses conducted from approximately 1800 to 2100 EDT. Each study area was censused for one morning and one evening by each of three observers. Morning and evening censuses were alternated for each area. The interval between consecutive census periods was 4 to 8 days. A census was postponed if weather conditions appeared to be restricting bird activity.

The entire width of the disturbed area was surveyed within the 200m boundaries of each study area. Birds up to approximately 50m beyond the study area boundaries were also recorded (including those in undisturbed forest above the highwall and below the outslope).

Aerial photographs of the study areas approximately 11 X 14in (27.9 X 35.6cm) in size were used as maps on which the following information was recorded:

1. The locations of singing males, non-singing adults (calling, drumming, or silent), and juveniles.
2. The locations of simultaneously singing males of the same species.
3. The locations of territorial disputes.

4. The direction of flight and landing site of any bird.
5. Nest sites.

Locations of individual birds were indicated by an abbreviation of the common name. Additional symbols were used to indicate singing status, sex, and accuracy of location. For example:

IB = Indigo bunting, singing male, precise location.
IB = Nonsinging male, exact location
IB+ = Female, exact location.
↑
←IB→ = Singing male, approximate location.
↓

Vegetation Survey

Units of similar vegetation were delineated within each disturbed area. In most cases Haufler's (1976) delineations were used. Where these delineations were not suitable (as where units were defined according to soil color) boundaries were modified or new vegetation units were established. Vertical aerial photographs were used to map the vegetation units of each study area.

Haufler's estimates of stem densities and woody species cover (recorded in July and August 1975) were used where feasible. Vegetation units with modified boundaries and units of the single new study area were surveyed for these data between 30 June and 7 July 1976 using Haufler's methods: Woody stem counts were conducted within a two-meter-wide belt-transect established on the longest axis of each vegetation unit. Stems were counted in size classes of less than 1m, 1-2m, 2-4m, 4m in height to 7.6cm DBH, and greater than 7.6cm DBH. For the entire unit, the percent ground cover of each species of woody vegetation was visually estimated (estimates of two observers were averaged).

For all twelve study areas the following vegetation data were recorded in each vegetation unit (ocular estimates of two observers were averaged):

1. Percent herbaceous cover, woody cover, and total vegetative cover.
2. Percent cover of vegetation in layers of less than 1m, 1-4m, and greater than 4m in height.
3. Percent volume of vegetation in layers of less than 1m, 1-4m, and greater than 4m in height (based on the percent of the volume of each layer occupied by vegetation).
4. Maximum vegetation height and average canopy height.

The general aspect (slope direction) and the average highwall height were recorded for each study area. Accurate distance measurements between reference points on the aerial photographs were recorded to compute map scales. The age of each study area was obtained from mining company records.

Derivation of Vegetation Variables

Accurate maps of each study area were drawn from vertical aerial photographs. From these maps, the size of each vegetation unit was determined with a compensating polar planimeter. These were summed to find the total size of each study area.

Although the length of each study area was initially held constant (200m), the sizes of the disturbed areas varied due to differences in width (from highwall to bottom of outslope). The calculated area sizes varied from 1.31 to 1.94 hectares. This variation, if unadjusted, would have made comparisons of bird populations between areas invalid. To avoid this problem, portions of the larger disturbed areas were cropped so that all study areas were equal in size (1.31ha). This was done by subtracting one-half of the excess area from each end of the original 200m long disturbed area. Vegetation measurements were then weighted by the size of each vegetation unit and averaged for each study area.

Foliage height diversity (FHD) was calculated in two ways, using the percent cover and the percent volume of vegetation in layers of less than 1m, 1-4m, and greater than 4m in height. The Shannon formula (Shannon and Weaver 1949) was used to compute FHD:

$$\mathrm{FHD} = H' = -\sum_{i=1}^{n} P_i \, \mathrm{Log}_e \, P_i$$

where P_i = the proportion of the total vegetation (the sum of the percent covers or the sum of the percent volumes) contributed by layer i.

Woody stem diversity indices were also calculated using the Shannon formula with P_i equal to the proportion of the total stem density contributed by stems in size catagory i.

In an attempt to evaluate habitat heterogeneity, a series of indices were developed to express the variability of several vegetation parameters within each study area. These indices were based on the Raw Index of Diversity developed by Graf (1973), which assumes that the greatest habitat diversity would be found on an area having equal proportions of different habitat types (maximum equitability). Heterogeneity indices for total cover, woody cover, herbaceous cover, and canopy cover were calculated as follows:

1. For each of these variables, it was assumed that the maximum diversity would exist if a given site were composed of equal areas in cover categories of 0-20, 21-40, 41-60, 61-80 and 81-100 percent.
2. The actual proportion of the total study area in each percent cover category was calculated.
3. The differences between the theoretically optimum proportion (E), which in the application was 0.20, and the observed proportions (O) were calculated for each percent cover category.
4. These differences were squared and summed over all

n categories. These values were then subtracted from 1 so that larger values indicated a higher degree of heterogeneity.

The equation is:

$$RID = 1 - \sum_{i=1}^{n} (E-O)^2$$

Two heterogeneity indexes were calculated for canopy height. Canopy height heterogeneity-3 was calculated assuming that a site with the theoretical maximum diversity would contain equal areas of vegetation with canopy heights of less than 1m, 1-4m, and greater than 4m ($E = 0.33$, $n = 3$). Canopy height heterogeneity-5 was calculated using five canopy height categories ($E = 0.20$, $n = 5$): 0-4.4m, 4.5-8.8m, 8.9-13.2m, 13.3-17.6m and 17.7-22.0m (the range of canopy heights was divided into five equal categories). Descriptions and abbreviations of all vegetation and site-factor variables included in the statistical analyses are presented in Table 2.

Derivation of Bird Population Variables

The recorded locations for each bird species were plotted on transparent overlays of the study area maps (disturbed areas were all 1.31ha in size). So that parameters for bird populations of the marginal undisturbed forest could also be obtained, marginal areas 15m wide (after Yahner 1973) and 200m long were delineated above the

Table 2. Descriptions and abbreviations of vegetation and site-factor variables for which relationships with breeding bird population parameters were analyzed.

Variable	Abbreviation	Description
Total vegetative cover	TOTCOVX	Percent ground cover of all vegetation
Woody cover	WOODCOVX	Percent cover of woody vegetation
Herbaceous cover	HERBCOVX	Percent cover of herbaceous vegetation
Cover 0-1m	COVAX	Percent cover of vegetation in the 0-1m layer
Cover 1-4m	COVBX	Percent cover of vegetation in the 1-4m layer
Sum of covers 0-4m	COVAXBX	COVAX + COVBX
Canopy cover	CANCOVX	Percent cover of vegetation in the 4+m layer
Sum of covers	COVDX	COVAX + COVBX + CANCOVX
Cover FHD	COVFHD	Foliage height diversity index (Shannon formula) with i = COVAX, COVBX, CANCOVX
Volume 0-1m	VOLAX	Percent volume of vegetation in the 0-1m layer
Volume 1-4m	VOLBX	Percent volume of vegetation in the 1-4m layer
Volume 0-4m	VOLAXBX	Percent volume of vegetation in the 0-4m layer

Table 2. Descriptions and abbreviations of vegetation and site-factor variables for which relationships with breeding bird population parameters were analyzed. (Continued)

Variable	Abbreviation	Description
Canopy volume	VOLCX	Percent volume of vegetation in the 4-24m layer (24m was maximum height of vegetation)
Total volume	VOLDX	Percent volume of vegetation in the 0-24m layer
Volume FHD	VOLFHD	Foliage height diversity index (Shannon formula) with i = VOLAX, VOLBX, VOLCX
Stems 0-1m	STEMAX	Density of woody stems 0-1m in height (stems/100m^2)
Stems 1-2m	STEMBX	Density of woody stems 1-2m in height (stems/100m^2)
Stems 2-4m	STEMCX	Density of woody stems 2-4m in height (stems/100m^2)
Stems 1-4m	STEMBXCX	Density of woody stems 1-4m in height (stems/100m^2)
Stems 4m-7.6cm DBH	STEMDX	Density of woody stems 4m in height to 7.6cm DBH (stems/100m^2)
Stems over 7.6cm DBH	STEMEX	Density of woody stems greater than 7.6cm DBH (stems/100m^2)

Table 2. Descriptions and abbreviations of vegetation and site-factor variables for which relationships with breeding bird population parameters were analyzed. (Continued)

Variable	Abbreviation	Description
Stems over 1m	STEMGR1	Density of woody stems greater than 1m in height (stems/100m^2)
Stems over 4m	STEMDXEX	Density of woody stems greater than 4m in height
Total stems	STEMTOT	Density of all woody stems
Stem index-3	STINDEX3	Woody stem diversity index (Shannon formula) with i = STEMAX, STEMBXCX, STEMDXEX
Stem index-4	STINDEX4	Woody stem diversity index (Shannon formula) with i = STEMBX, STEMCX, STEMDX, STEMEX
Stem index-5	STINDEX5	Woody stem diversity index (Shannon formula) with i = STEMAX, STEMBX, STEMCX, STEMDX, STEMEX
Weighted stems 1-4m	WSBXCX	2(STEMBX) + 3(STEMCX)
Weighted stems over 1m	WSGR1	2(STEMBX) + 3(STEMCX) + 4(STEMDX) + 5(STEMEX)
Weighted stems over 4m	WSDXEX	4(STEMDX) + 5(STEMEX)
Weighted total stems	WSTOT	WSGR1 + STEMAX

Table 2. Descriptions and abbreviations of vegetation and site-factor variables for which relationships with breeding bird population parameters were analyzed. (Continued)

Variable	Abbreviation	Description
Weighted stem index-3	WSDEX3	Woody stem diversity index (Shannon formula) with i = STEMAX, WSBXCX, WSDXEX
Weighted stem index-4	WSDEX4	Woody stem diversity index (Shannon formula) with i = 2(STEMBX), 3(STEMCX), 4(STEMDX), 5(STEMEX)
Weighted stem index-5	WSDEX5	Woody stem diversity index (Shannon formula) with i = STEMAX, 2(STEMBX), 3(STEMCX), 4(STEMDX), 5(STEMEX)
Canopy height	CANHGTX	Average canopy height (m)
Woody species	WOODSPEC	Number of woody species contributing to at least 2% cover of the disturbed area
Total cover heterogeneity	TCOVHET	Index of total cover heterogeneity using categories of 0-20%, 21-40%, 41-60%, 61-80%, and 81-100% cover
Woody cover heterogeneity	WCOVHET	Index of woody cover heterogeneity using categories of 0-20%, 21-40%, 41-60%, 61-80%, and 81-100% cover
Herbaceous cover heterogeneity	HERBHET	Index of herbaceous cover heterogeneity using categories of 0-20%, 21-40%, 41-60%, 61-80%, and 81-100% cover

Table 2. Descriptions and abbreviations of vegetation and site-factor variables for which relationships with breeding bird population parameters were analyzed. (Continued)

Variable	Abbreviation	Description
Canopy cover heterogeneity	CCVHET	Index of canopy cover heterogeneity using categories of 0-20%, 21-40%, 41-60%, 61-80%, and 81-100% cover
Canopy height heterogeneity-3	CHTHET3	Index of canopy height heterogeneity using height categories of 0-1m, 1-4m, and greater than 4m
Canopy height heterogeneity-5	CHTHET5	Index of canopy height heterogeneity using height categories of 0-4.4m, 4.5-8.8m, 8.9-13.2m, 13.3-17.6m, and 17.7-22.0m
Heterogeneity index-1	HETER1	WCOVHET + HERBHET + CHTHET5
Heterogeneity index-2	HETER2	TCOVHET + CCVHET + CHTHET5
Heterogeneity index-3	HETER3	TCOVHET + CCVHET + CHTHET3
Age	AGE	Age of the disturbed area (years)
Aspect	ASPECT	The aspect of the disturbed area (compass degrees - 180)
Highwall height	HIGHWALL	Height of the highwall (m)
Disturbed area width	WIDTH	Average width of the disturbed area (m)

Table 2. Descriptions and abbreviations of vegetation and site-factor variables for which relationships with breeding bird population parameters were analyzed. (Continued)

Variable	Abbreviation	Description
Undisturbed border	EDGE	Total length of the borders between the disturbed and marginal areas
Outslope area	OUTSLOPE	Percent of the disturbed area comprised of outslope

highwall and below the outslope on each study area map. Bird population parameters were then determined for each disturbed, marginal (upper and lower margins combined), and total study area (disturbed and marginal areas combined).

To be considered as breeding, a species must have been recorded within or beyond the total study area boundaries during at least two of the six census periods, as recommended by Robbins (1970). Those species recorded during only one census period were considered as visitors. The locations of simultaneously singing males and territorial conflicts, as well as clusters of recorded locations, were used to differentiate territories of the same species. Each territory, whether complete or partial, was considered equivalent to a breeding pair. For the Brown-headed Cowbird (Molothrus ater), which does not establish a breeding territory, the number of pairs was estimated by the highest number of males recorded during any census period.

Breeding pairs and visiting species of the total study area were those for which at least one contact (exact location) was recorded within the total study area boundaries. These were further categorized as breeding pairs and visiting species of the disturbed or marginal areas, the criterion for which was a single contact in either area. The numbers of breeding species, breeding pairs, and observed species (breeding or visiting) were then determined for each disturbed, marginal and total study area. Bird species diversity (BSD) was calculated for each disturbed, marginal, and total study area using the Shannon formula as follows:

$$BSD = H' = -\sum_{i=1}^{n} P_i \, Log_e \, P_i$$

where n = the number of breeding species.

P_i = the proportion of the total number of breeding pairs contributed by pairs of species i.

Table 3 lists abbreviations of the bird population variables used in the remainder of the text.

Analysis of Data

All statistical analyses were conducted using the SAS 76 statistical analysis system (Barr et al. 1976) available through the V.P.I. & S.U. Computing Center. Breeding bird population parameters of the disturbed, marginal, and total study areas were analyzed separately for relationships with the vegetation and site-factor variables. The population parameters were considered as dependent variables and the vegetation and site-factor parameters were considered as independent variables.

The first SAS 76 procedure used was PROC RSQUARE which performed regressions of each population variable on each independent variable and on all possible combinations of two independent variables. The output listed the 50 variables or combinations of variables which best explained the

Table 3. Abbreviations of bird population variables included in analyses for relationships with vegetation and site-factor variables of 12 abandoned contour mines in southwest Virginia.

Variable	Variable abbreviation
Number of breeding species of the disturbed area	SD
Number of breeding pairs of the disturbed area	PD
Bird species diversity index of the disturbed area	BD
Total observed species of the disturbed area	TD
Number of breeding species of the marginal area	SM
Number of breeding pairs of the marginal area	PM
Bird species diversity index of the marginal area	BM
Total observed species of the marginal area	TM
Number of breeding species of the total study area	ST
Number of breeding pairs of the total study area	PT
Bird species diversity index of the total study area	BT
Total observed species of the total study area	TT

variation in each population variable. The procedure PROC STEPWISE was then employed to obtain regression equations and the significance levels of included variables. The procedure PROC SCATTER was used to produce a series of graphs on which each dependent variable was plotted against each independent variable.

RESULTS

A total of 50 species was observed within the boundaries of the 12 study areas (see Appendix I for common and scientific names of these species). Of these, 47 satisfied the requirements for being considered as breeding species. Within the disturbed study areas, a total of 48 species was recorded, of which 45 were breeding species. Forty-seven species were observed within the marginal areas, of which 44 were considered as breeding. The minimum, maximum, and mean values of the number of breeding species, number of breeding pairs, bird species diversity, and total observed species for the disturbed, marginal, and total study areas are presented in Table 4. The above values and a list of the species observed for each disturbed, marginal, and total study area are included in Appendices II, III, and IV, respectively.

The disturbed areas ranged in age from 11 to 27 years. Total vegetative cover for each disturbed area ranged from 23 to 94 percent. The minimum, maximum, and mean values of each vegetation and site-factor variable are presented in Table 5. The values of these variables for each study area are included in Appendix V.

Linear regression analysis revealed that the percent volume of vegetation in the 0-1m layer accounted for the most variation in the number of breeding species of the disturbed area. The equation for that regression line shows a positive

Table 4. Minimum, maximum, and mean values of breeding bird population parameters for 12 study areas on abandoned contour mines in southwest Virginia.

Variable	Minimum value	Maximum value	Mean
Number of breeding species of the disturbed area	15	27	20.4
Number of breeding pairs of the disturbed area	18	35	25.2
Bird species diversity index of the disturbed area	2.66	3.23	2.93
Total observed species of the disturbed area	17	29	22.2
Number of breeding species of the marginal area	16	24	20.4
Number of breeding pairs of the marginal area	19	34	25.7
Bird species diversity index of the marginal area	2.72	3.10	2.93
Total observed species of the marginal area	18	29	23.0
Number of breeding species of the total study area	16	32	24.2
Number of breeding pairs of the total study area	22	44	31.4
Bird species diversity index of the total study area	2.71	3.38	3.07
Total observed species of the total study area	21	34	28.1

Table 5. Minimum, maximum, and mean values for vegetation and site-factor variables of 12 disturbed study areas on abandoned contour mines in southwest Virginia.

Variable	Minimum value	Maximum value	Mean
Total vegetative cover (%)	23.4	94.2	67.2
Woody Cover (%)	15.4	89.8	53.3
Herbaceous Cover (%)	11.1	59.5	34.9
Cover 0-1m (%)	19.4	65.4	44.8
Cover 1-4m (%)	11.4	68.9	38.4
Sum of covers 0-4m (%)	31.4	132.1	83.3
Canopy cover (%)	4.7	79.6	38.4
Sum of covers (%)	36.1	213.7	122.4
Cover FHD	0.955	1.095	1.049
Volume 0-1m (%)	15.7	54.2	31.3
Volume 1-4m (%)	6.7	56.9	26.8
Volume 0-4m (%)	9.0	52.1	28.0
Canopy Volume (%)	0.4	40.9	14.6
Total Volume (%)	2.2	38.0	16.9
Volume FHD	0.735	1.082	0.919
Stems 0-1m (/100m^2)	17.4	118.0	53.7
Stems 1-2m (/100m^2)	5.2	3.5	13.6
Stems 2-4m (/100m^2)	1.9	16.2	8.5
Stems 1-4m (/100m^2)	7.1	52.5	22.1
Stems 4m-7.6cm DBH (/100m^2)	0.7	18.2	6.3
Stems over 7.6cm DBH (/100m^2)	0.1	11.0	3.9
Stems over 1m (/100m^2)	7.9	70.4	32.2
Stems over 4m (/100m^2)	0.8	26.6	10.1
Total stems (/100m^2)	36.0	173.6	85.9
Stem index-3	0.447	1.008	0.834
Stem index-4	0.901	1.376	1.149
Stem index-5	0.526	1.360	1.074

Table 5. Minimum, maximum, and mean values for vegetation and site-factor variables of 12 disturbed study areas on abandoned contour mines in southwest Virginia. (Continued)

Variable	Minimum value	Maximum value	Mean
Weighted stems 1-4m (/100m^2)	16.1	114.0	52.7
Weighted stems over 1m (/100m^2)	19.5	194.3	97.1
Weighted stems over 4m (/100m^2)	3.4	117.5	44.4
Weighted total stems (/100m^2)	57.8	309.7	150.8
Weighted stem index-3	0.726	1.077	0.994
Weighted stem index-4	1.006	1.362	1.242
Weighted stem index-5	0.904	1.587	1.399
Canopy height (m)	3.3	17.1	9.3
Woody species	6.0	14.0	9.9
Total cover heterogeneity	0.268	0.901	0.601
Woody cover heterogeneity	0.381	0.930	0.685
Herbaceous cover heterogeneity	0.541	0.934	0.788
Canopy cover heterogeneity	0.324	0.831	0.635
Canopy height heterogeneity-3	0.497	0.960	0.751
Canopy height heterogeneity-5	0.531	0.943	0.803
Heterogeneity index-1	0.583	1.759	1.276
Heterogeneity index-2	0.611	1.400	1.039
Heterogeneity index-3	0.362	1.532	0.987
Age (yrs)	11.0	27.0	18.0
Aspect (Compass degrees - 180)	10.0	180.0	81.0
Highwall height (m)	7.6	45.7	19.0
Disturbed area width (m)	63.0	105.0	88.0
Undisturbed border (m)	290.0	400.0	358.0
Outslope area (%)	4.3	62.2	30.7

relationship between these two variables:

$$SD = 13.93 + 0.207(VOLAX) \quad (r^2 = 0.632)$$

The graph of this relationship is presented in Fig. 2. Other independent variables which showed a significant ($p < 0.05$) relationship with SD were COVAX, COVAXBX, and HERBCOVX. Each of these variables also had a positive slope.

The best linear regression equations for the dependent variables PD, BD, and TD contained the variable COVAX or VOLAX. In all three equations, the slope of the independent variable was positive:

$$PD = 12.01 + 0.293(COVAX) \quad (r^2 = 0.807)$$

$$BD - 2.67 + 0.00831(VOLAX) \quad (r^2 = 0.439)$$

$$TD = 13.50 + 0.193(COVAX) \quad (r^2 = 0.701)$$

The best five linear regression equations for SD, PD, BD, and TD are presented in Table 6.

The best five two-variable multiple regression equations for SD each included either TOTCOVX or COVAXBX with a positive slope and a stem density variable with a negative slope. The best two variable model for SD was:

$$SD = 12.22 + 0.195(TOTCOVX) - 0.784(STEMDX) \quad (R^2 = 0.905)$$

All variables in the model were significant at the 0.01 level.

The best two-variable models for PD, BD, and TD also included either TOTCOVX or COVAXBX with a positive slope and

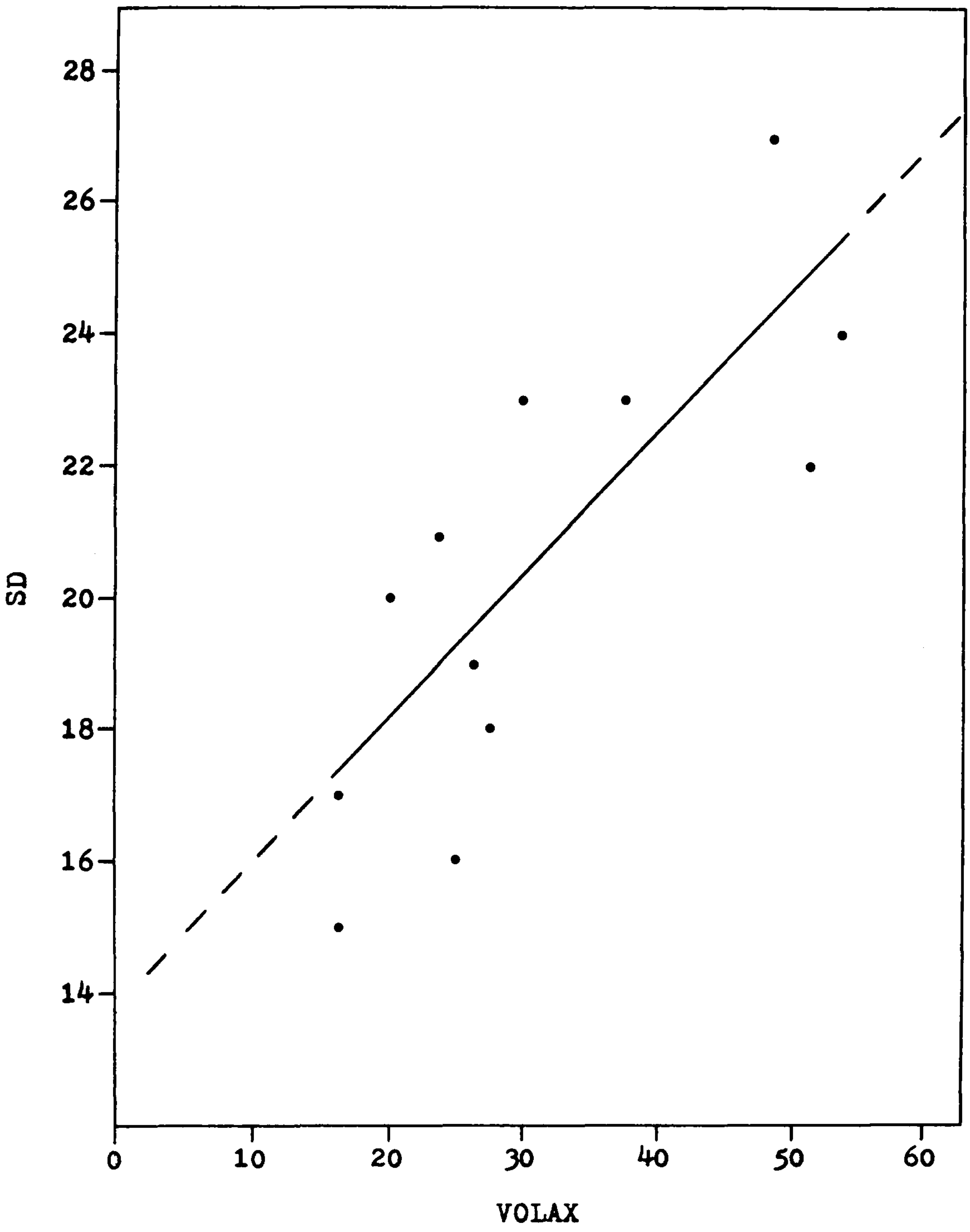

Fig. 2. Graph of the regression line (y = 13.93 + 0.207x) depicting the relationship between the number of breeding species of the disturbed area (SD) and the percent volume of vegetation in the 0-1m layer (VOLAX) for 12 study areas on abandoned contour mines in southwest Virginia.

Table 6. Linear regression equations for bird population parameters of 12 disturbed study areas on abandoned contour mines in southwest Virginia.

Equations	r^2
SD = 13.93 + 0.207(VOLAX)	0.632**
SD = 12.98 + 0.166(COVAX)	0.599**
SD = 14.47 + 0.0714(COVAXBX)	0.389*
SD = 16.03 + 0.126(HERBCOVX)	0.389*
SD = 16.44 + 0.142(VOLAXBX)	0.300
PD = 12.01 + 0.293(COVAX)	0.807**
PD = 16.24 + 0.256(HERBCOVX)	0.693**
PD = 15.23 + 0.148(TOTCOVX)	0.539**
PD = 9.06 + 1.62(WOODSPEC)	0.506**
PD = 16.89 + 0.0676(COVDX)	0.488*
BD = 2.67 + 0.00831(VOLAX)	0.438*
BD = 2.65 + 0.00641(COVAX)	0.386*
BD = 2.36 + 0.00643(DISWIDE)	0.315
BD = 4.06 - 0.00322(EDGE)	0.292
BD = 2.58 + 0.551(CCVHET)	0.259
TD = 13.50 + 0.193(COVAX)	0.701**
TD = 16.60 + 0.160(HERBCOVX)	0.540**
TD = 15.99 + 0.197(VOLAX)	0.493*
TD = -5.01 + 21.89(WSDEX4)	0.399*
TD = 16.29 + 0.0874(TOTCOVX)	0.377*

** Significant at the 0.01 level.

* Significant at the 0.05 level.

a stem density variable with a negative slope:

$$PD = 11.75 + 0.227(COVAXBX) - 0.0565(WSGR1) \quad (R^2 = 0.923)$$
$$BD = 2.61 + 0.00826(TOTCOVX) - 0.366(STEMDX) \quad (R^2 = 0.737)$$
$$TD = 12.86 + 0.207(TOTCOVX) - 0.733(STEMDX) \quad (R^2 = 0.863)$$

All variables in these equations were significant at the 0.01 level. The best five two-variable regression models for SD, PD, BD, and TD are presented in Table 7.

The variation in the number of breeding species of the marginal area was best explained by the stem density variable WSTOT. The equation for that relationship was:

$$SM = 24.95 - 0.0300(WSTOT) \quad (r^2 = 0.669)$$

The graph of this equation is presented in Fig. 3. The best five linear regression equations for SM all contained stem density variables with a negative slope.

All of the best five linear regression equations for PM, BM, and TM contained stem density variables with a negative slope. The best single-variable models for PM, BM, and TM were:

$$PM = 32.35 - 0.207(STEMGR1) \quad (r^2 = 0.527)$$
$$BM = 3.16 - 0.00149(WSTOT) \quad (r^2 = 0.690)$$
$$TM = 27.77 - 0.0491(WSGR1) \quad (r^2 = 0.745)$$

The best five linear regression equations for SM, PM, BM, and TM are presented in Table 8. Of the best 50 two-variable

Table 7. Multiple regression equations for bird population parameters of 12 disturbed study areas on abandoned contour mines in southwest Virginia.

Equations	R^2
SD = 12.22 + 0.195(TOTCOVX) - 0.784(STEMDX)	0.905**
SD = 12.30 + 0.189(TOTCOVX) - 0.454(STEMDXEX)	0.830**
SD = 12.39 + 0.186(TOTCOVX) - 0.101(WSDXEX)	0.809**
SD = 12.67 + 0.131(COVAXBX) - 0.311(STEMDXEX)	0.786**
SD = 12.63 + 0.131(COVAXBX) - 0.070(WSDXEX)	0.782**
PD = 11.75 + 0.227(COVAXBX) - 0.0564(WSGR1)	0.923**
PD = 12.36 + 0.221(COVAXBX) - 0.172(STEMGR1)	0.914**
PD = 11.54 + 0.269(COVAXBX) - 0.164(WOODCOVX)	0.893**
PD = 11.46 + 0.199(COVAXBX) - 0.452(STEMDX)	0.879**
PD = 13.12 + 0.203(COVAXBX) - 0.0321(WSTOT)	0.874*
BD = 2.61 + 0.00826(TOTCOVX) - 0.0366(STEMDX)	0.737**
BD = 2.17 + 0.0130(VOLAXBX) + 0.404(HETER30)	0.651*
BD = 2.64 + 0.00526(COVAXBX) - 0.0238(STEMDX)	0.633*
BD - 1.80 + 0.00741(DISWIDE) + 0.574(STINDEX3)	0.627*
BD = 2.62 + 0.00777(TOTCOVX) - 0.0204(STEMDXEX)	0.626**
TD = 12.86 + 0.207(TOTCOVX) - 0.733(STEMDX)	0.863**
TD = 13.60 + 0.161(COVAXBX) - 0.0494(WSGR1)	0.853**
TD = 14.85 + 0.146(COVAXBX) - 0.0322(WSTOT)	0.845**
TD = 13.21 + 0.141(COVAXBX) - 0.445(STEMDX)	0.843**
TD = 12.91 + 0.144(COVAXBX) - 0.272(STEMDXEX)	0.822**

** All independent variables significant at the 0.01 level.

* All independent variables significant at the 0.05 level.

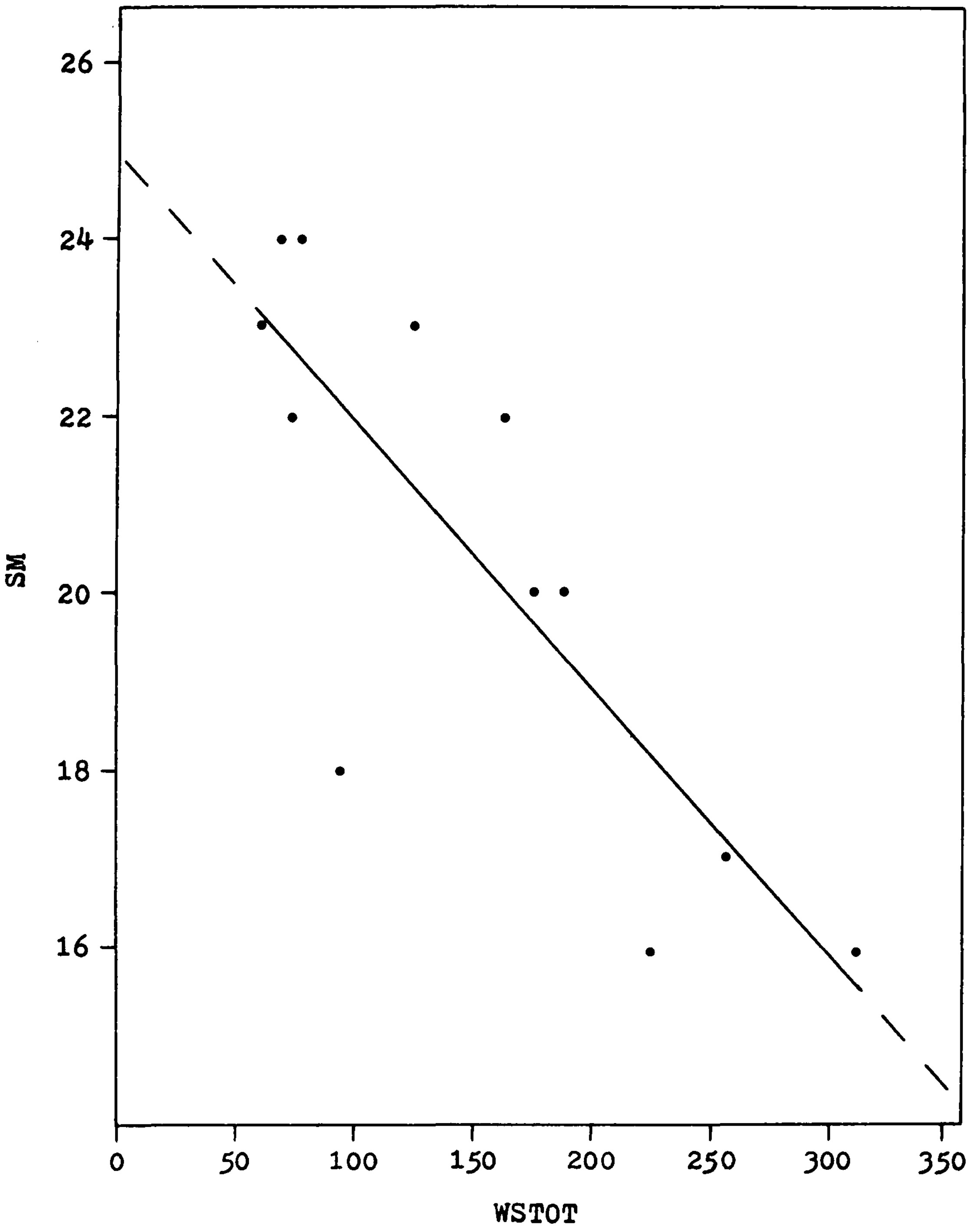

Fig. 3. Graph of the regression line ($y = 24.95 - 0.0300x$) depicting the relationship between the number of breeding species of the marginal area (SM) and the density of total weighted stems per $100m^2$ (WSTOT) for 12 study areas on abandoned contour mines in southwest Virginia.

Table 8. Linear regression equations for bird population parameters of 12 marginal study areas on abandoned contour mines in southwest Virginia.

Equations	r^2
SM = 24.95 - 0.0300(WSTOT)	0.669**
SM = 24.33 - 0.0403(WSGR1)	0.649**
SM = 24.47 - 0.126(STEMBXCX)	0.603**
SM - 22.94 - 0.249(STEMDXEX)	0.595**
SM = 22.92 - 0.0564(WSDXEX)	0.594**
PM = 32.35 - 0.207(STEMGR1)	0.527**
PM = 31.76 - 0.0627(WSGR1)	0.503**
PM = 32.53 - 0.130(WSBXCX)	0.436*
PM = 32.02 - 0.0421(WSTOT)	0.423*
PM = 29.15 - 0.344(STEMDXEX)	0.365*
BM = 3.16 - 0.00149(WSTOT)	0.690**
BM = 3.17 - 0.00273(STEMTOT)	0.654**
BM = 3.12 - 0.00190(WSGR1)	0.609**
BM = 3.05 - 0.0118(STEMDXEX)	0.567**
BM = 3.06 - 0.0193(STEMDX)	0.565**
TM = 27.77 - 0.0491(WSGR1)	0.745**
TM = 26.06 - 0.302(STEMDXEX)	0.682**
TM = 26.04 - 0.0684(WSDXEX)	0.679**
TM = 27.87 - 0.151(STEMGR1)	0.678**
TM = 26.07 - 0.491(STEMDX)	0.670**

** Significant at the 0.01 level.

* Significant at the 0.05 level.

models for SM, only three contained variables which were all significant at the 0.05 level. The best two-variable model for SM was:

$$SM = 39.95 - 16.02(CHTHET3) - 0.0772(WSGR1) \quad (R^2 = 0.862)$$

All variables in this model were significant at the 0.01 level. The other two models with significant variables contained VOLAX with a positive slope and a stem density variable with a negative slope.

The best two-variable regression models for PM, BM, and TM were:

$$PM = 58.03 - 26.95(CHTHET3) - 0.125(WSGR1) \quad (R^2 = 0.697)$$

$$BM = 3.83 - 0.731(CHTHET3) - 0.00359(WSGR1) \quad (R^2 = 0.796)$$

$$TM = 31.29 - 0.356(AGE) - 0.049(WSDXEX) \quad (R^2 = 0.815)$$

All variables in these models were significant at the 0.05 level. The best five two-variable models for SM, PM, BM and TM are presented in Table 9. These include models with the highest R^2 values in which all variables were significant at the 0.05 level, and those models with the highest R^2 values where there were less than five models containing significant variables.

The linear regression equation which accounted for the most variation in the number of breeding species of the total study area was:

$$ST = 26.96 - 0.276(STEMDXEX) \quad (r^2 = 0.366)$$

Table 9. Multiple regression equations for bird population parameters of 12 marginal study areas on abandoned contour mines in southwest Virginia.

Equations	R^2
SM = 39.95 - 16.02(CHTHET3) - 0.0772(WSGR1)	0.862**
SM = 22.12 + 0.101(VOLAX) - 0.151(STEMGR1)	0.788*
SM = 22.23 + 0.0824(VOLAX) - 0.453(WSGR1)	0.777*
SM = 22.14 + 0.0466(COVAXBX) - 0.0577(WSGR1)	0.762
SM = 23.51 + 0.0523(HERBCOVX) - 0.0326(WSTOT)	0.758
PM + 58.03 - 26.95(CHTHET3) - 0.125(WSGR1)	0.697*
PM - 53.22 - 21.28(CHTHET3) - 0.359(STEMGR1)	0.672
PM = 27.36 + 0.142(TOTCOVX) - 0.115(WSGR1)	0.665
PM - 28.47 + 0.0851(COVAXBX) - 0.307(STEMGR1)	0.655
PM - 37.41 + 0.230(COVAX) - 1.285(AGE)	0.636*
BM = 3.83 - 0.731(CHTHET3) - 0.00359(WSGR1)	0.796*
BM = 3.08 + 0.0293(VOLAX) - 0.00156(WSTOT)	0.763
BM = 3.10 + 0.00212(HERBCOVX) - 0.00159(WSTOT)	0.752
BM = 3.32 + 0.00814(VOLAX) - 0.0372(AGE)	0.748**
BM = 3.02 + 0.00471(VOLAX) - 0.00709(STEMGR1)	0.730*
TM = 31.29 - 0.356(AGE) - 0.0490(WSDXEX)	0.815*
TM = 31.23 - 0.351(AGE) - 0.217(STEMDXEX)	0.813*
TM = 32.09 - 0.425(AGE) - 0.465(STEMEX)	0.806*
TM = 30.67 - 7.972(CCVHET) - 0.258(STEMDXEX)	0.804*
TM = 32.16 - 0.438(AGE) - 0.106(VOLCX)	0.787*

** All independent variables significant at the 0.01 level.

* All independent variables significant at the 0.05 level.

This relationship was significant at the 0.05 level, however, the r^2 value was considerably lower than those of the one-variable equations for SD and SM. The graph of the relationship between ST and STEMDXEX is presented in Fig. 4.

There were no linear regression models for PT significant at the 0.05 level. The best single-variable models for BT and TT both contained the variable STEMDX with a negative slope:

$$BT = 3.22 - 0.0219(STEMDX) \quad (r^2 = 0.466)$$

$$TT = 30.76 - 0.428(STEMDX) \quad (r^2 = 0.406)$$

The best five linear regression equations for ST, PT, BT, and RT are presented in Table 10.

The best five two-variable multiple regression equations for ST contained VOLAX or TOTCOVX with a positive slope and a stem density variable with a negative slope. The best two-variable model for ST was:

$$ST = 20.65 + 0.216(VOLAX) - 0.552(STEMDX) \quad (R^2 = 0.812)$$

All variables in the model were significant at the 0.01 level.

The best two-variable equations for PT, BT, and TT were:

$$PT = 24.60 + 0.217(COVAXBX) - 0.117(WSGR1) \quad (R^2 = 0.646)$$

$$BT = 2.98 + 0.00789(VOLAX) - 0.0245(STEMDX) \quad (R^2 = 0.804)$$

$$TT = 25.64 + 0.131(COVAX) - 0.550(STEMDX) \quad (R^2 = 0.698)$$

All variables in the models for PT and BT were significant at

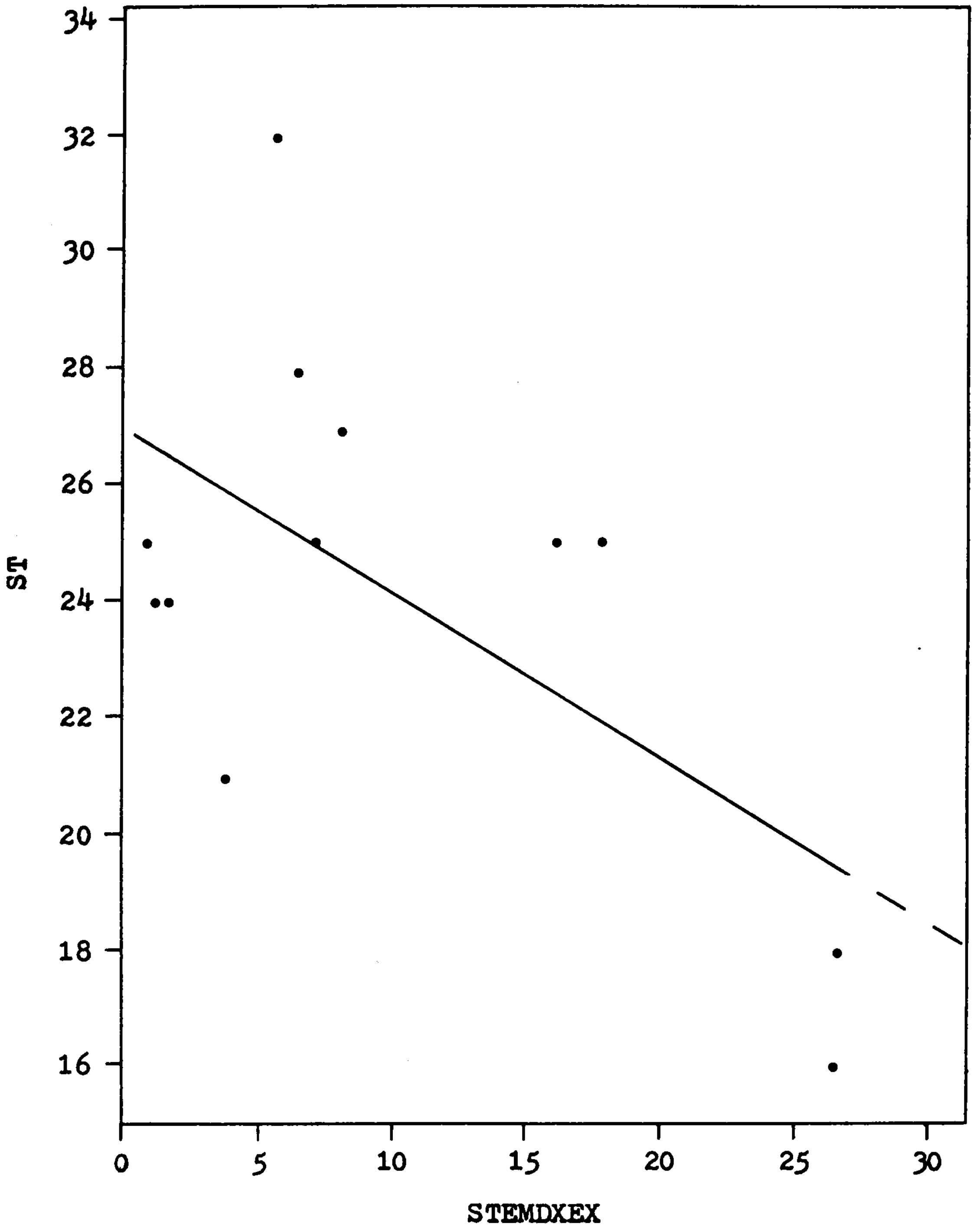

Fig. 4. Graph of the regression line (y = 26.96 - 0.276x) depicting the relationship between the number of breeding species of the total study area (ST) and the density of stems greater than 4m in height per $100m^2$ (STEMDXEX) for 12 study areas on abandoned contour mines in southwest Virginia.

Table 10. Linear regression equations for bird population parameters of 12 total study areas on abandoned contour mines in southwest Virginia.

Equations	r^2
ST = 26.96 - 0.276(STEMDXEX)	0.366*
ST = 26.99 - 0.451(STEMDX)	0.365*
ST = 26.94 - 0.0623(WSDXEX)	0.363*
ST = 18.33 + 0.186(VOLAX)	0.357*
ST = 15.65 + 12.44(WCOVHET)	0.321
PT = 24.47 + 0.199(HERBCOVX)	0.297
PT = 22.08 + 0.208(COVAX)	0.288
PT = 20.47 + 8.58(HETER10)	0.237
PT = 24.30 + 0.227(VOLAX)	0.230
PT = 12.01 + 24.18(CHTHET5)	0.201
BT = 3.22 - 0.0219(STEMDX)	0.466*
BT - 3.21 - 0.0129(STEMDXEX)	0.438*
BT = 3.21 - 0.00292(WSDXEX)	0.431*
BT = 3.18 - 0.0264(STEMEX)	0.330
BT = 3.27 - 0.00127(WSTOT)	0.324
TT = 30.76 - 0.428(STEMDX)	0.406*
TT = 30.61 - 0.249(STEMDXEX)	0.371*
TT = 30.57 - 0.0561(WSDXEX)	0.364*
TT = 31.37 - 0.0338(WSGR1)	0.282
TT = 31.78 - 0.0245(WSTOT)	0.276

** Significant at the 0.01 level.

* Significant at the 0.05 level.

the 0.01 level. All variables in the model for TT were significant at the 0.05 level. The best five two-variable models for ST, PT, BT, and TT are presented in Table 11.

Table 11. Multiple regression equations for bird population parameters of 12 total study areas on abandoned contour mines in southwest Virginia.

Equations	R^2
ST = 20.65 + 0.216(VOLAX) - 0.552(STEMDX)	0.837**
ST = 19.55 + 0.166(TOTCOVX) - 0.648(STEMDXEX)	0.812**
ST = 19.61 + 0.164(TOTCOVX) - 0.145(WSDXEX)	0 798**
ST = 19.79 + 0.162(TOTCOVX) - 1.042(STEMDX)	0.796**
ST = 20.87 + 0.201(VOLAX) - 0.297(STEMDXEX)	0.779**
PT = 24.70 + 0.217(COVAXBX) - 0.117(WSGR1)	0.646**
PT = 24.05 + 0.326(COVAXBX) - 0.370(WOODCOVX)	0.645**
PT = 25.38 + 0.307(TOTCOVX) - 0.150(WSGR1)	0.625**
PT = 26.27 + 0.270(HERBCOVX) - 0.679(STEMDX)	0.620*
PT = 22.98 + 0.282(COVAX) - 0.672(STEMDX)	0.606*
BT = 2.98 + 0.00789(VOLAX) - 0.0245(STEMDX)	0.804**
BT = 2.95 + 0.00597(TOTCOVX) - 0.0437(STEMDX)	0.782**
BT = 2.95 + 0.00587(TOTCOVX) - 0.0261(STEMDXEX)	0.738*
BT = 4.13 - 1.027(CHTHET3) - 0.0275(STEMDXEX)	0.727*
BT = 2.99 + 0.00716(VOLAX) - 0.0137(STEMDXEX)	0.722*
TT = 25.64 + 0.131(COVAX) - 0.550(STEMDX)	0.698*
TT = 25.46 + 0.120(TOTCOVX) - 0.863(STEMDX)	0.696*
TT - 25.79 + 0.0794(COVAXBX) - 0.689(STEMDX)	0.674*
TT = 25.25 + 0.0871(COVAXBX) - 0.436(STEMDXEX)	0.670*
TT = 27.40 + 0.117(HERBCOVX) - 0.544(STEMDX)	0.669*

** All independent variables significant at the 0.01 level.

* All independent variables significant at the 0.05 level.

DISCUSSION

Breeding Bird Populations of the Disturbed areas

The results of the linear regression analyses indicate that, in general, bird populations of the disturbed areas were most strongly influenced by the development of the ground layer (0-1m) vegetation. The dependent variables for the volume and cover of vegetation in the 0-1m layer accounted for approximately 63 and 60 percent, respectively, of the variation observed in the number of breeding species. The best linear regression equations for the number of breeding pairs, bird species diversity, and total observed species also included VOLAX or COVAX. These trends are probably best explained by the importance of this layer of vegetation as nesting cover. In Pennsylvania, Preston and Norris (1947) located 741 nests (of all species) within a 36.5ha study area containing a variety of cover types and found that 44 percent of these nests were within 3 feet of the ground. The findings of Monson (1941) and Dambach (1944) in their studies of the effects of controlled grazing also suggest the importance of ground layer vegetation to breeding birds.

Multiple regression analyses revealed additional trends within the best five two-variable models for SD, PD, BD, and TD. Of these 20 equations, 12 contained the variable for the sum of covers of the 0-1m and 1-4m layers, and six contained the variable for total vegetative cover. Both COVAXBX and TOTCOVX, when included, consistently had a positive slope.

Stem density variables with a negative slope were included in 17 equations. Twelve of these equations contained stem density variables for stems greater than 4m in height. Four of the remaining equations included weighted stem density variables which placed greater emphasis on stems of the larger size categories.

The negative stem density variables were apparently included in the multiple regression models to account for decreases in the population parameters that occurred among the study areas which had a high degree of revegetation. The four mines in this vegetative class (R, S, Y, and Z) had revegetated to the extent that they could be described as young forests. The best two-variable equation for SD contained TOTCOVX with a positive slope and STEMDX with a negative slope. The graphs of SD versus TOTCOVX and SD versus STEMDX are presented in Figs. 5 and 6, respectively. From these graphs, it is apparent that the mines which deviated the most from overall positive trends were mines Y and Z. At comparable values of total cover, these mines supported lower numbers of breeding species than did mines R and S. Mines Y and Z also had considerably higher densities of trees greater than 4m in height to 7.6cm DBH. Thus, for mines having comparable values of TOTCOVX, those having higher values of STEMDX supported less diverse bird populations. The graph of the relationship between SD and COVAXBX also showed that mines Y and Z deviated in a negative manner

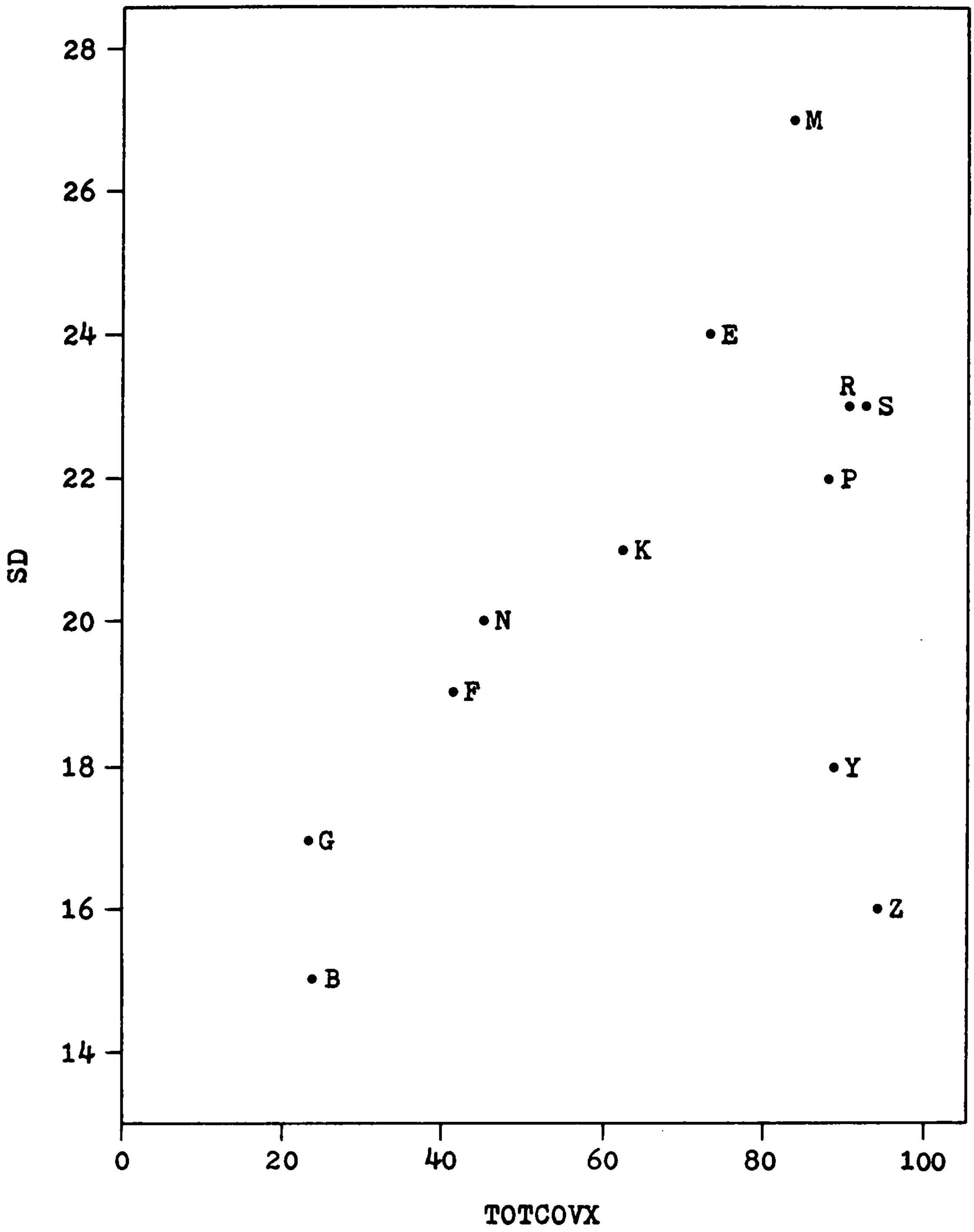

Fig. 5. Graph of the relationship between the number of breeding species of the disturbed area (SD) and the percent total vegetative cover (TOTCOVX) for 12 study areas on abandoned contour mines in southwest Virginia.

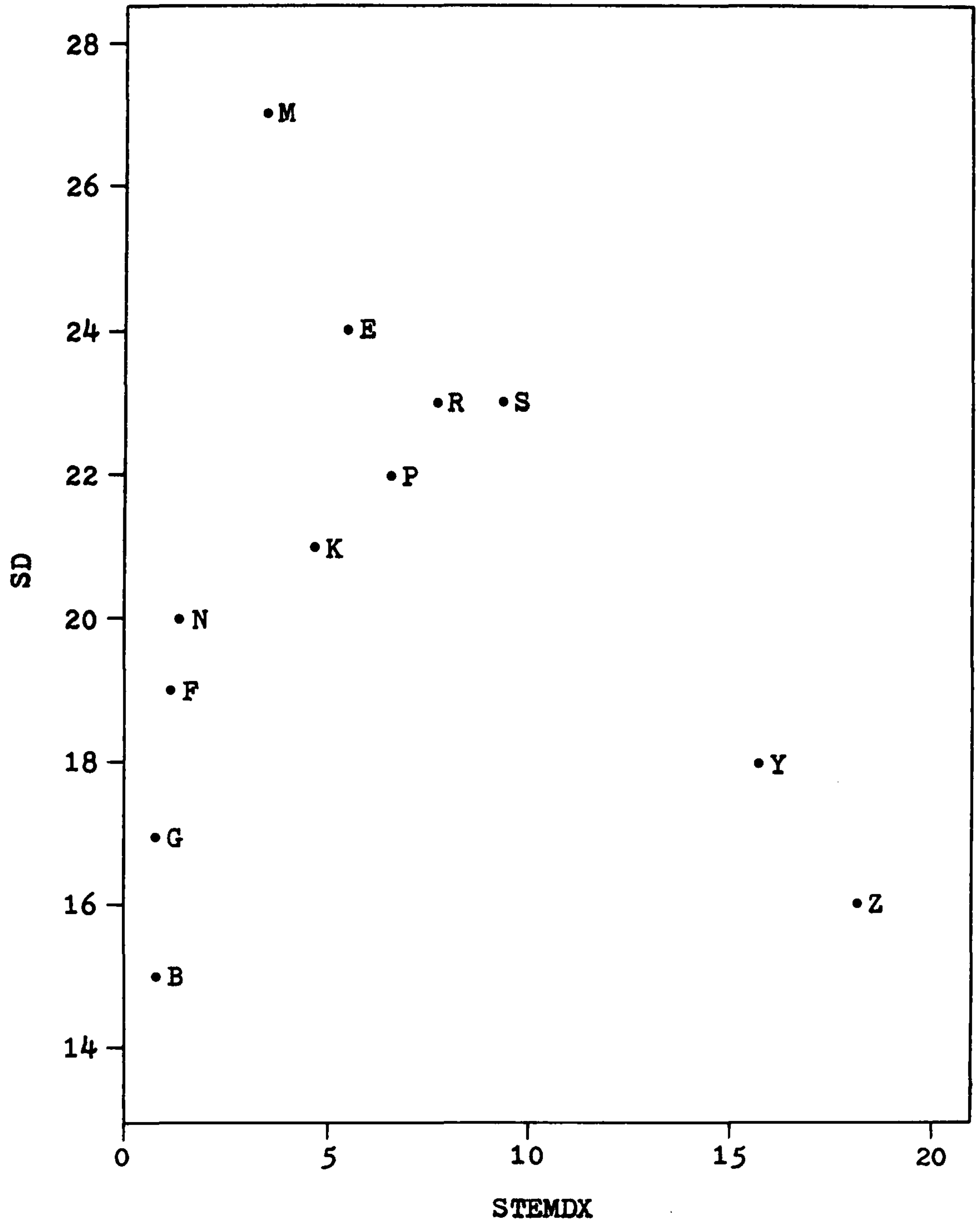

Fig. 6. Graph of the relationship between the number of breeding species of the disturbed area (SD) and the density of stems 4m in height to 7.6cm DBH per 100m^2 (STEMDX) for 12 study areas on abandoned contour mines in southwest Virginia.

from an overall positive trend. Trends similar to these were apparent in graphs of the relationships between the dependent variables PD, BD, and TD and the independent variables COVAXBX and TOTCOVX.

The negative slopes of the stem density variables for stems greater than 4m in height suggest that higher degrees of canopy development adversely affected all four parameters of the breeding bird populations. The most plausible explanation for this relationship is that canopy coverage may have been extensive enough on mines Y and Z to affect a reduction in the understory vegetation. The graph of the relationship between SD and the percent canopy cover of the disturbed areas (Fig. 7) illustrates that mines Y and Z did have higher degrees of canopy cover than did mines R and S. The percent volume of vegetation in the 0-1m layer was somewhat lower on mines Y and Z (28 and 24 percent, respectively) than on mines R and S (30 and 38 percent, respectively). However, a more notable difference occurred in the percent volume of vegetation in the 1-4m layer (21 and 39 percent for mines Y and Z, respectively, versus 56 and 57 percent for mines R and S, respectively). Though CANCOVX was not included in any of the best five multiple regression equations for SD, PD, BD, or TD, it was included as a significant variable in several models with lower R^2 values and it consistently had a negative slope. The negative influence of canopy closure on understory development and breeding bird populations has been

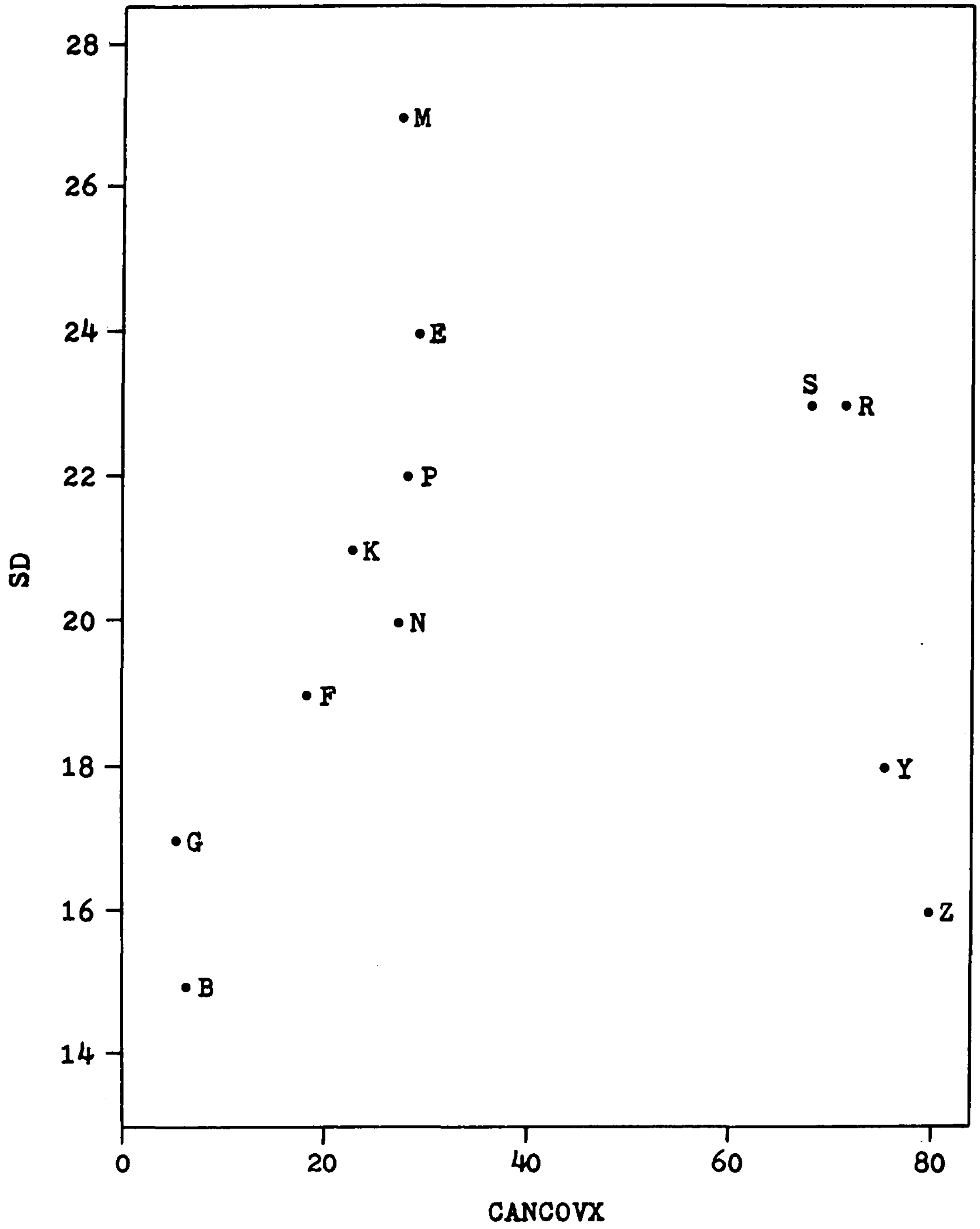

Fig. 7. Graph of the relationship between the number of breeding species of the disturbed area (SD) and the percent canopy cover (CANCOVX) for 12 study areas on abandoned contour mines in southwest Virginia.

previously reported by several investigators (Conner and Adkisson 1975, Ambrose 1975, Hooper et al. 1973, Odum 1950).

It is appropriate to note here that neither of the foliage height diversity indices were included in the best five linear or multiple regression equations for SD, PD, BD, and TD. This was not unexpected as MacArthur (1964) pointed out that FHD was useful as a predictor of bird populations only within homogeneous habitats.

Because orphan mines, in general, are vegetated heterogeneously, it was anticipated that heterogeneity variables would be frequently included in the regression models. However, of the 40 linear and multiple regression equations presented, only one contained a heterogeneity variable significant at the 0.05 level. The variable, HETER3, was computed by summing the values of total cover heterogeneity, canopy cover heterogeneity, and canopy height heterogeneity-3 (canopy height categories were 0-1m, 1-4m, and greater than 4m). It was included in a two-variable model for BD:

$$BD = 2.64 + 0.00526(VOLAXBX) + 0.404(HETER3) \quad (R^2 = 0.651)$$

Thus, values of BD would increase as the amount of vegetation in the 0-1m and 1-4m layers increased and as units within the area became more heterogeneous in total cover, canopy cover, and canopy height. Several other heterogeneity variables showed, graphically, positive relationships with bird population parameters. Among the most apparent of these relationships was that between SD and CHTHET5 (canopy height heterogeneity calculated with five height categories). From the graph of SD versus CHTHET5 (Fig. 8), it is apparent that with the exception of a single mine, the number of breeding species showed a positive relationship with the heterogeneity of canopy heights among the vegetation units of each study area.

Thus, it can be concluded that breeding bird populaations of the disturbed areas showed positive relationships with several aspects of vegetational development, but only until canopy cover of the forested areas became extensive enough to restrict understory growth. Thereafter, a decrease in bird population parameters was observed. Also, habitat variability, as indexed by several heterogeneity variables, apparently had a positive influence on bird populations.

Breeding Bird Populations of the Marginal Areas

Linear regression analyses revealed that bird populations of the marginal areas were negatively influenced by increasing densities of woody stems on the disturbed areas. All of the best five linear regression equations for SM, PM, BM, and TM contained a stem density variable with a negative slope. However, the stem density variables were not predominantly those for trees greater than 4m in height as was the case with the multiple regression equations for SD, PD, BD, and TD. The variables included in the best equations for SM, PM, BM, and TM were weighted total stems, stems greater than 1m in

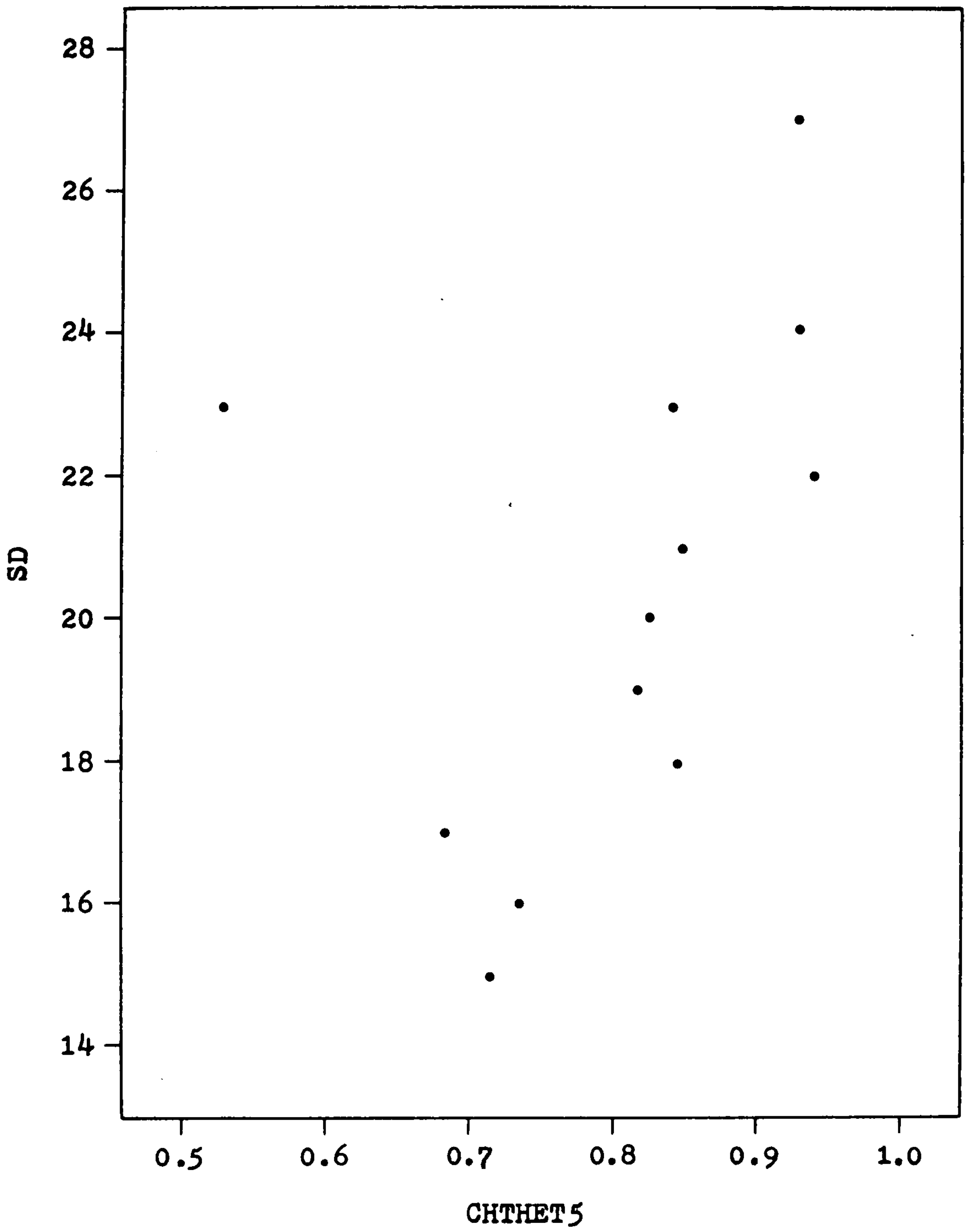

Fig. 8. Graph of the relationship between the number of breeding species of the disturbed area (SD) and a canopy height heterogeneity variable (CHTHET5) for 12 study areas on abandoned contour mines in southwest Virginia.

height, weighted total stems, and weighted stems greater than 1m in height, respectively. Thus, increasing densities of trees and shrubs on the disturbed areas had a negative effect on all four population parameters of the marginal areas.

The most plausible explanation for the trends revealed by the linear regression analyses involves the edge effect resultant from the junctures of the disturbed and marginal areas. As shrub and tree densities increased on the disturbed areas, the vegetational differences between the disturbed areas and the surrounding undisturbed forest diminished. The edge effect almost certainly decreased as well, resulting in progressively lower bird populations of the marginal areas.

Multiple regression analyses revealed additional trends within the best five two-variable models for SM, PM, BM, and TM. Of the 13 equations in which all variables were significant at the 0.05 level, four contained the variable for the volume of vegetation in the 0-1m layer. This variable consistently had a positive slope. Stem density variables with a negative slope were included in 10 of the 13 equations. The majority of these variables were for stems greater than 1m in height. The age of the disturbed area was included in six models and always had a negative slope. Four of the 13 equations contained the variable canopy height heterogeneity-3 (calculated with categories of less than 1m, 1-4m, and greater than 4m in height) with a negative slope.

Graphs of the relationships between the four population parameters and the previously mentioned variables did not show consistent trends which would help to explain why these variables were included in the multiple regression models. However, some conclusions can be made based on the slopes of these variables.

The variable VOLAX (with a positive slope) may have been included because the marginal area populations included many individuals of the disturbed area populations which, as discussed earlier, showed positive relationships with several ground layer vegetation variables. However, the positive relationships between the marginal area population variables and VOLAX might also be explained in terms of the edge effect resulting from the juncture of the disturbed and undisturbed areas. The value of the edge to breeding birds may have been a function of the amount of ground layer vegetation on the disturbed area, as understory growth may have been restricted in the undisturbed forest.

The negative stem density variables were probably included for the reason previously discussed. That AGE was included with a negative slope suggests that bird populations of the marginal areas might have been negatively influenced by some more comprehensive aspect of disturbed area vegetation or by other habitat factors which the independent variables did not adequately describe.

A possible explanation for why the canopy height heterogeneity variable was included with a negative slope involves the availability of singing posts. As the disturbed areas, particularly those in earlier successional stages, became more heterogeneous in canopy heights, the variety of singing post heights also increased. This would have allowed males of species typical of disturbed areas which prefer tall trees as song posts and were otherwise largely restricted to the marginal forest to more frequently advertise their territorial boundaries from song posts on the disturbed areas. Thus, populations of the marginal areas may have decreased somewhat as these species "moved out" to the disturbed areas.

In summary, breeding bird populations of the marginal areas appeared to be most strongly influenced, in a negative manner, by the revegetation of the disturbed areas in terms of increasing densities of trees and shrubs. This trend probably reflected a continuing decline in the edge effect with the reforestation of the disturbed areas.

Breeding Bird Populations of the Total Study Areas

The best linear regression equations for the population variables of the total study areas, with the exception of BT, had considerably lower r^2 values than those for the population parameters of the disturbed and marginal areas. The best equation for ST had an r^2 value of only 0.366 compared to r^2 values of 0.669 and 0.862 for SD and SM, respectively. These lower r^2 values may have resulted from the contradictory trends observed for the bird populations of the disturbed and marginal areas.

There were no equations for PT which were significant at the 0.05 level, and only 10 of the 15 equations for ST, BT, and TT were significant. Of these 10 equations, nine contained a stem density variable with a negative slope for stems greater than 4m in height.

The equation for ST with the highest r^2 value contained the variable for the density of stems greater than 4m in height. The graph of the relationship between ST and STEMDXEX (Fig. 9) shows that most of the variation in the data was contributed by the mines with a low or intermediate degree of revegation. It is also apparent that for those mines the relationship between ST and STEMDXEX was positive. However, the relationship was clearly negative for those mines which had a high degree of revegetation where higher densities of these stems resulted in lower numbers of breeding species. Graphs of relationships between the population variables BT and TT and the included stem density variables showed trends very similar to that of ST versus STEMDXEX. Thus these relationships were similar to those which were observed for the disturbed area population variables.

Multiple regression analyses for ST, PT, BT, and TT revealed several trends similar to those which were observed for the disturbed area population variables. The variables TOTCOVX and COVAXBX were included in seven and four equations, respectively. These variables consistently

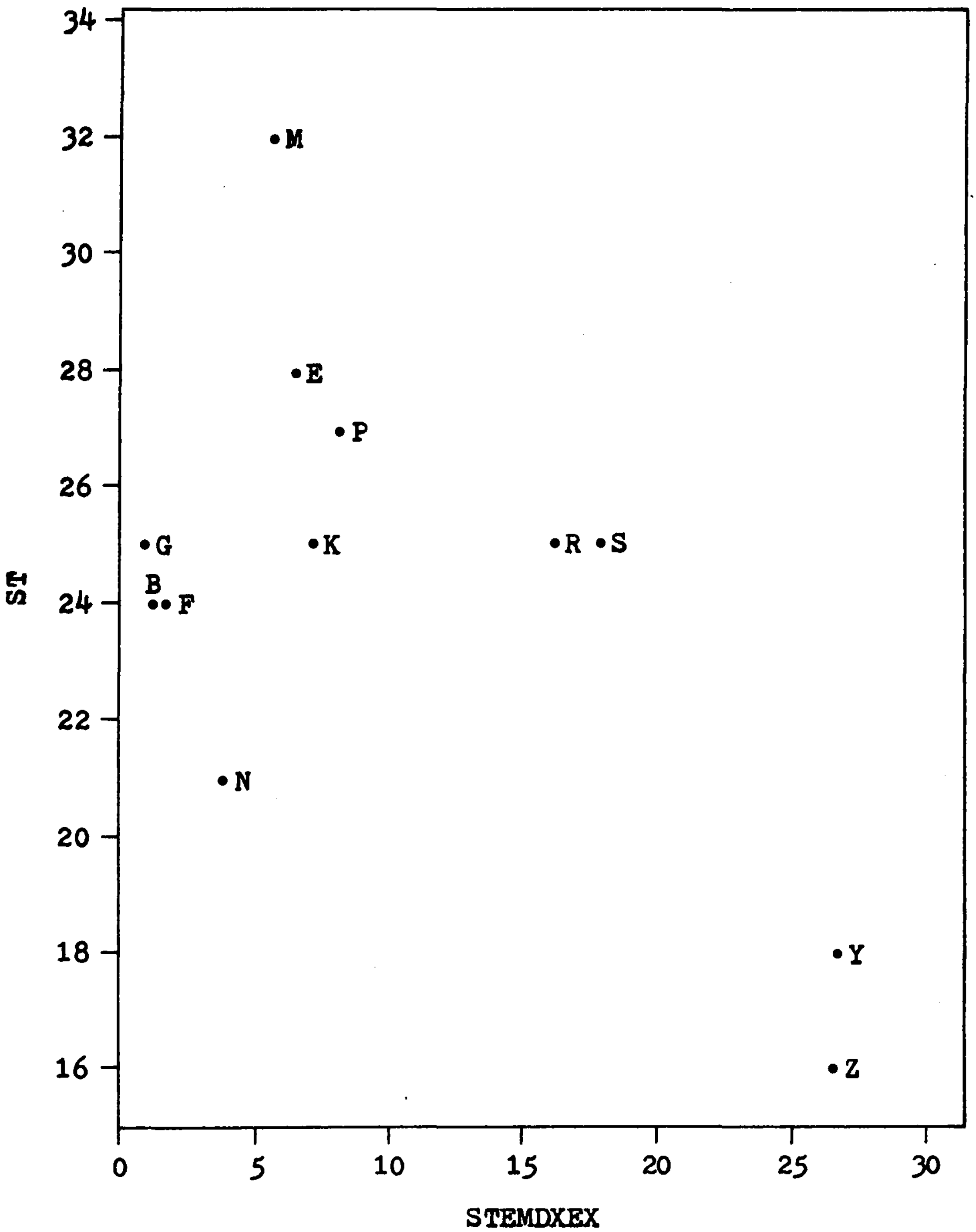

Fig. 9. Graph of the relationship between the number of breeding species of the total study area (ST) and the density of stems greater than 4m in height per $100m^2$ (STEMDXEX) for 12 study areas on abandoned contour mines in southwest Virginia.

had a positive slope. Ground layer vegetation variables (with a positive slope) were also frequently included. The variable VOLAX was included in four equations, and COVAX and HERBCOVX were each included in two equations. Stem density variables with a negative slope were included in 19 equations. Of these, 17 contained variables for stems greater than 4m in height.

The best two-variable model for ST contained VOLAX with a positive slope and STEMDX with a negative slope. The graph of the relationship between ST and VOLAX (Fig. 10) shows that the mines which deviated the most from the overall trend were mines Y and Z. The graph of the relationship between ST and STEMDX (Fig. 11) shows that mines Y and Z had the highest values of STEMDX and supported the lowest numbers of breeding species. Also, the relationship between these two variables was apparently positive for those mines having a low or intermediate degree of revegetation. Thus, STEMDX with a negative slope was apparently included in the equation to account for the deviations of mines Y and Z from a positive relationship between SD and VOLAX. Graphs of the relationships between PT, BT, and TT and their included variables also showed that mines Y and Z consistently deviated in a negative manner from overall positive trends. Thus, the stem density variables were apparently included with a negative slope in these models to account for the deviations of mines Y and Z. As previously discussed, the higher degrees of canopy cover

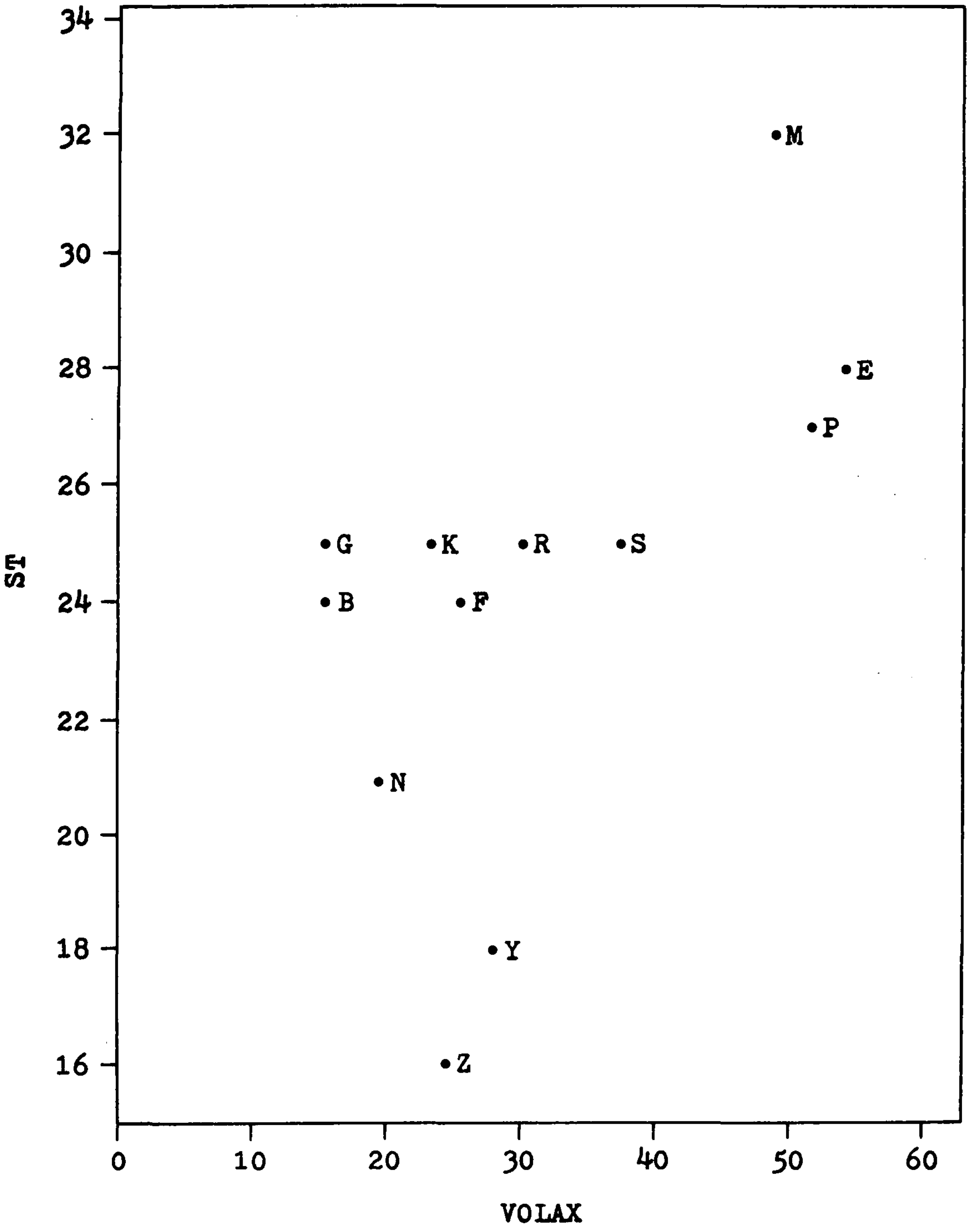

Fig. 10. Graph of the relationship between the number of breeding species of the total study area (ST) and the percent volume of vegetation in the 0-1m layer (VOLAX) for 12 study areas on abandoned contour mines in southwest Virginia.

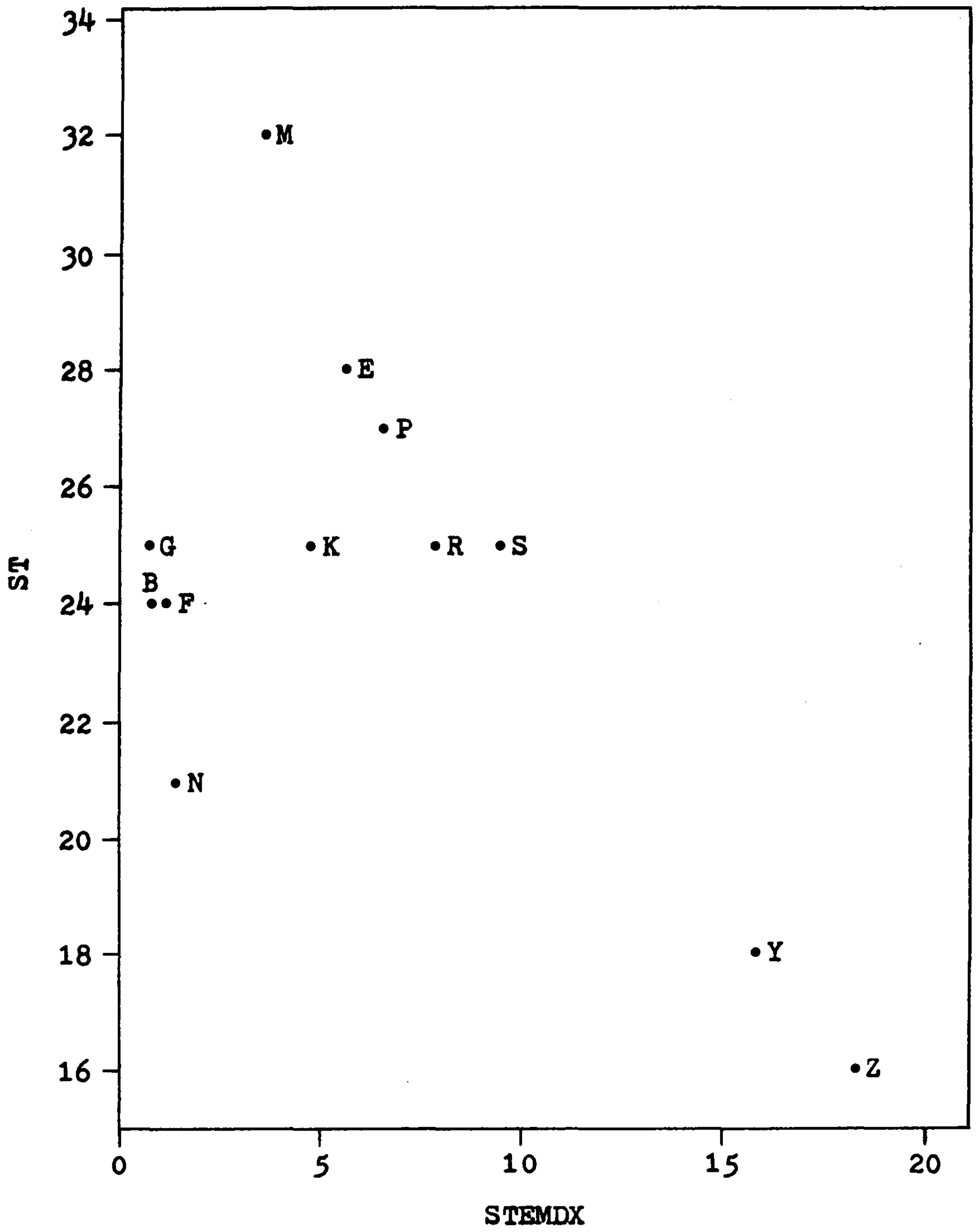

Fig. 11. Graph of the relationship between the number of breeding species of the total study area (ST) and the density of stems 4m in height to 7.6cm DBH per 100m^2 (STEMDX) for 12 study areas on abandoned contour mines in southwest Virginia.

of mines Y and Z apparently affected a reduction in the amount of understory vegetation. This apparently resulted in a decline in the bird populations of the total study areas as it did in the bird populations of the disturbed areas.

Thus, bird populations of the total study areas showed positive relationships with several aspects of the vegetational development of the disturbed areas until canopy closure apparently affected a decline in populations through a reduction in the amount of understory vegetation. The similarity of these trends with those observed for the disturbed areas suggests that birds restricted to the marginal areas constituted a relatively small proportion of the total study area populations.

Evaluation of Abandoned Contour Mines as Breeding Bird Habitats

Because it is unlikely that sections of orphan mines considered for reclamation will be equal in size, the equations presented here should not be used to predict parameters of bird populations per se, but to obtain values by which the habitat quality of these areas can be compared on a relative basis. It is also unlikely that orphan mine habitats will be evaluated in terms of their value to breeding bird populations of the marginal areas alone. Therefore, only the equations for the population parameters of the disturbed and total study areas will be considered here.

Regression equations selected for use in habitat evaluation should contain variables for which values can be obtained quickly and with a minimum of expertise, and have R^2 values sufficiently high to provide confidence in the evaluations. Also, groups of equations for different population parameters should be selected which all contain the same variable(s) so that several habitat evaluations could be made from a single set of vegetation measurements. The equations presented here are those which best satisfy these criteria.

Before any reclamation work is begun, it is reasonable to assume that disturbed areas will have to be surveyed in some manner. This will be necessary to determine the problems caused by each mine and to assign priorities for reclamation. Aerial photography and/or on-site inspection are likely to be employed as survey techniques.

If only on-site surveys are planned, certain vegetation estimates should be obtained for use in breeding bird habitat evaluation. If time does not permit the estimation of more than one vegetation parameter, either the percent cover or the percent volume of vegetation in the 0-1m layer should be estimated. Either of these estimates could be quickly obtained and would provide the values for COVAX or VOLAX for use in the following sets of equations (significant at the 0.05 level):

$$SD = 12.98 + 0.166(COVAX) \qquad (r^2 = 0.599)$$

$$PD = 12.01 + 0.293(COVAX) \qquad (r^2 = 0.807)$$

$$BD = 2.65 + 0.00641(COVAX) \qquad (r^2 = 0.386)$$

$$TD = 13.50 + 0.193(COVAX) \quad (r^2 = 0.701)$$

$$SD = 13.93 + 0.207(VOLAX) \quad (r^2 = 0.632)$$

$$BD = 2.67 + 0.00831(VOLAX) \quad (r^2 = 0.438)$$

$$TD = 15.99 + 0.197(VOLAX) \quad (r^2 = 0.493)$$

$$ST = 18.33 + 0.186(VOLAX) \quad (r^2 = 0.357)$$

Habitats could be evaluated with greater confidence (in terms of the R^2 values of the equations) if estimates of total vegetative cover and the densities of stems 4m in height to 7.6cm DBH and of stems greater than 7.6cm DBH could be obtained. Although total vegetative cover could be quickly estimated in the field, estimates of stem densities would require a considerable amount of time and effort to obtain. However these would provide the values for STEMDX, STEMDXEX, and WSDXEX for use in combination with TOTCOVX in the equations presented in Table 12.

If aerial photographs are available, these should be used to map vegetation units while in the field. This would save time over sketch-mapping and provide a more accurate basis for habitat evaluation. Also, values for total vegetative cover could be obtained from aerial photographs, leaving only the previously mentioned stem density estimates to be obtained on-site before the equations in Table 12 could be used for habitat evaluations.

In the event that aerial photography is the only survey technique employed, total vegetative cover would be the variable for which values could be most accurately obtained.

Table 12. Multiple regression equations containing variables for total vegetative cover (TOTCOVX) and the densities of stems greater than 4m in height (STEMDX, STEMDXEX, and WSDXEX).

Equations	R^2
$SD = 12.22 + 0.195(\mathrm{TOTCOVX}) - 0.784(\mathrm{STEMDX})$	0.905**
$SD = 12.30 + 0.189(\mathrm{TOTCOVX}) - 0.454(\mathrm{STEMDXEX})$	0.830**
$SD = 12.67 + 0.186(\mathrm{TOTCOVX}) - 0.101(\mathrm{WSDXEX})$	0.809**
$BD = 2.61 + 0.00826(\mathrm{TOTCOVX}) - 0.0366(\mathrm{STEMDX})$	0.737**
$BD = 2.62 + 0.00777(\mathrm{TOTCOVX}) - 0.0204(\mathrm{STEMDXEX})$	0.626**
$TD = 12.86 + 0.207(\mathrm{TOTCOVX}) - 0.733(\mathrm{STEMDX})$	0.863**
$ST - 19.55 + 0.166(\mathrm{TOTCOVX}) - 0.648(\mathrm{STEMDXEX})$	0.812**
$ST - 19.61 + 0.164(\mathrm{TOTCOVX}) - 0.145(\mathrm{WSDXEX})$	0.798**
$ST = 19.79 + 0.162(\mathrm{TOTCOVX}) - 1.042(\mathrm{STEMDX})$	0.796**
$BT - 2.95 + 0.00597(\mathrm{TOTCOVX}) - 0.0437(\mathrm{STEMDX})$	0.782**
$BT = 2.95 + 0.00587(\mathrm{TOTCOVX}) - 0.0261(\mathrm{STEMDXEX})$	0.738*
$TT = 25.46 + 0.120(\mathrm{TOTCOVX}) - 0.863(\mathrm{STEMDX})$	0.696*

** All independent variables significant at the 0.01 level.

* All independent variables significant at the 0.05 level.

This variable, by itself, was not a good predictor of any population variable when all 12 disturbed or total study areas were included in the regression. However, strong relationships were apparent (graphically) between several population variables and TOTCOVX for the eight mines which had a low or intermediate degree of revegetation. These study areas were more representative of mines which would likely be considered for reclamation than were the forested study areas. It is therefore appropriate to consider equations derived from regressions of population variables on TOTCOVX, using the observations of these eight mines, for use in evaluating habitats of orphan mines which are not forested. The following equations for the relationships between the population variables and TOTCOVX were significant at the 0.05 level:

$$SD = 13.23 + 0.134(TOTCOVX) \quad (r^2 = 0.805)$$
$$PD = 12.79 + 0.208(TOTCOVX) \quad (r^2 = 0.922)$$
$$BD = 2.67 + 0.00507(TOTCOVX) \quad (r^2 = 0.520)$$
$$TD = 14.26 + 0.138(TOTCOVX) \quad (r^2 = 0.785)$$

Because total vegetative cover could be estimated from aerial photographs, these equations could also be used to evaluate more quickly a large number of disturbed areas than could be done by on-site inspections.

The equations presented here should also be used to evaluate potential reclamation planting strategies. The growth rates of many species used in reclamation plantings are known or can be approximated. Using these growth rates, future values of the vegetation variables could be approximated. Habitats resultant from various reclamation strategies could then be evaluated. The results of these modeling efforts should serve as feedback into the reclamation decision making process.

Reclaiming Abandoned Contour Mines to Benefit Breeding Birds

Many of the relationships revealed by this study should be considered in the derivation of reclamation plans. This study and others have indicated the importance of a well developed ground layer of vegetation to breeding birds. It is therefore suggested that reclamation planners consider the manner in which the vegetational development of this stratum will be affected by various planting strategies. Plantings of herbs and shrubs, where feasible, would affect a rapid increase in the cover and volume of vegetation in this layer. On the other hand, extensive plantings of trees alone would do little to increase the amount of vegetation in this layer and would eventually contribute to a reduction in ground layer vegetation through canopy closure and shading.

Bird populations of the unforested study areas showed positive relationships with several vegetation variables including total cover, the sum of covers of the 0-1m and 1-4m layers, stem density variables for stems greater than 4m in height, and average canopy cover. These trends suggest that for areas in early successional stages, efforts should be made to establish quickly a high degree of vegetative cover, and also to provide for the future development of the higher vegetational strata. Plantings of tree seedlings interspersed among plantings of herbs and shrubs would achieve both of these objectives.

Several indices of vegetational heterogeneity showed positive relationships with bird populations of the disturbed areas. This suggests that wherever possible, the heterogeneity of vegetative cover types should be maintained or augmented through well interspersed plantings of several forms of vegetation.

Most people think of reclamation only in terms of the establishment of vegetation. However, often the reclamation of orphan mines will also involve the destruction of a considerable amount of existing vegetation through the bulldozing of access roads and the operation of heavy machinery on the area to be reclaimed. In these instances, a special effort should be made to preserve areas of dense ground layer vegetation, tall trees (on disturbed areas in early successional stages), and any vegetational features which appear to be lacking in the surrounding area.

SUMMARY AND CONCLUSIONS

In general, bird population parameters of the disturbed and total study areas increased with the vegetational development of the disturbed areas. However, bird populations decreased when canopy closure apparently affected a reduction in understory vegetation. Bird populations of the marginal areas decreased with the reforestation of the disturbed areas, apparently reflecting a decrease in the edge effect.

Several vegetation variables were frequently included in linear and multiple regression equations for the population variables of the disturbed and total study areas. These included variables for the percent cover and percent volume of vegetation in the 0-1m layer, total vegetative cover, and the densities of stems greater than 4m in height. Regression equations containing these variables were presented for use in habitat evaluation. If on-site surveys are conducted, estimates of total vegetative cover, and the densities of stems 4m in height to 7.6cm DBH and of stems greater than 7.6cm DBH should be obtained. These would provide values for variables included in several regression equations which could then be used to evaluate orphan contour mines as breeding bird habitats.

Also presented were a set of equations derived from regressions of population variables on the variable for total vegetative cover, with only the observations for eight unforested orphan mines included in the analyses. These should be used to evaluate habitats of orphan mines in early successional stages if aerial surveys alone are conducted.

Relationships revealed for bird populations of the disturbed and total study areas suggest that reclamation efforts should strive to achieve a high degree of vegetative cover and to increase the amount of ground layer vegetation. The future development of higher vegetational strata should also be provided for. However, this should be done in a manner which will not promote rapid canopy closure. Finally, these vegetational features should be introduced in such a way as to augment existing vegetational heterogeneity.

LITERATURE CITED

Ambrose, R. E. 1975. The effect of clearcutting on bird and small mammal populations. Ph.D. Thesis. Univ. Tennessee, Knoxville. 311pp.

American Ornithologists' Union, Committee on Classification and Nomenclature. 1957. Check-list of North American Birds, 5th ed. AOU, Baltimore MD 691pp.

American Ornithologists' Union, Committee on Classification and Nomenclature. 1973. Thirty-second supplement to the American Ornithologists' Union check-list of North American birds. Auk 90:411-419.

American Ornithologists' Union, Committee on Classification and Nomenclature. 1976. Thirty-third supplement to the American Ornithologists' Union check-list of North American birds. Auk 93:875-879.

Barr, A. J., J. H. Goodnight, J. P. Sall, and J. T. Helwig. 1976. A user's guide to SAS 76. SAS Institute, Inc., Raleigh, NC. 329pp.

Boccardy, J. A., and W. M. Spaulding, Jr. 1968. Effects of surface mining on fish and wildlife in Appalachia. U.S. Bur. Sport Fish. and Wildl. Resour. Publ. No. 65. 20pp.

Conner, R. N., and C. S. Adkisson, 1975. Effects of clear-cutting on the diversity of breeding birds. J. Forestry 73:781-785.

Dambach, C. A. 1944. A ten-year ecological study of adjoining grazed and ungrazed woodlands in northeastern Ohio. Ecol. Monogr. 14:255-270.

Dietrich, R. V. 1970. Geology and Virginia. Univ. of Virginia Press, Charlottesville. 213pp.

Garton, A. W. 1974. A comparative study of breeding-bird populations on two strip-mined areas. M.S. Thesis. Univ. Tennessee, Knoxville. 94pp.

Graf, R. L. 1973. Methods for delineating wildlife and other environmental management regions. M.S. Thesis. Virginia Polytechnic Inst. and State Univ., Blacksburg. 164pp.

Haufler, J. B. 1976. Factors influencing the revegetation success of orphan mines in southwest Virginia. M.S. Thesis. Virginia Polytechnic Inst. and State Univ., Blacksburg. 59pp.

Hooper, R. G., III. 1967. The influence of habitat disturbances on bird populations. M.S. Thesis. Virginia Polytechnic Inst., Blacksburg. 132pp.

__________________, H.S. Crawford, and R. F. Harlow. 1973. Bird density and diversity as related to vegetation in forest recreation areas. J. Forestry 71:766-769.

Johnston, D. W., and E. P. Odum. 1956. Breeding bird populations in relation to plant succession in the Piedmont of Georgia. Ecol. 37:50-62.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinois. Condor 70:348-357.

__________, and R. R. Roth. 1971. Vegetation structure and avian diversity in several New World areas. Am. Nat. 105:423-435.

MacArthur, R. H. 1964. Environmental factors affecting bird species diversity. Am. Nat. 98:387-397.

________________, and J. W. MacArthur. 1961. On bird species diversity. Ecol. 42:594-598.

________________, J. W. MacArthur, and J. Preer. 1962. On bird species diversity. II. Prediction of bird census from habitat measurements. Am. Nat. 96:167-174.

________________, H. F. Recher, and M. L. Cody. 1966. On the relation between habitat selection and species diversity. Am. Nat. 100:319-332.

Monson, G. 1941. The effect of revegetation on the small bird population in Arizona. J. Wildl. Manage. 5:395-397.

National Oceanic and Atmospheric Administration. 1974. Climates of the States. Vol. I. Water Information Center, Inc. Port Washington, NY. 480pp.

National Oceanic and Atmospheric Administration. 1976. Climatological data: Virginia. National Climatic Center. Asheville, NC. Vol. 86. Nos. 3-6.

Odum, E. P. 1950. Bird populations of the Highlands (North Carolina) Plateau in relation to plant succession and avian invasion. Ecol. 31:587-605.

Preston, F. W., and R. T. Norris. 1947. Nesting heights of breeding birds. Ecol. 28:241-273.

Recher, H. F. 1969. Bird species diversity and habitat diversity in Australia and North America Am. Nat. 103:75-80.

Robbins, C. S., ed. 1970. An international standard for a mapping method in bird census work recommended by the International Bird Census Committee. Audubon Field Notes 24:723-726.

Roth, R. R. 1976. Spatial heterogeneity and bird species diversity. Ecol. 57:773-782.

Shannon, C. E., and W. Weaver. 1949. The mathematical theory of Communication. Univ. of Illinois Press, Urbana. 117pp.

Shugart, H. H., Jr., and D. James. 1973. Ecological succession of breeding bird populations in northwestern Arkansas. Auk 90:62-77.

Tennessee Valley Authority. [1975]. An action program for Virginia's abandoned coal mines. A proposal to the Office of Management and Budget. 37pp. + 6 illus.

U.S. Bureau of Mines. 1943. Minerals yearbook 1941. U.S. Govt. Printing Office, Washington, D.C. 1573pp.

__________________ 1949. Minerals yearbook 1947. U.S. Govt. Printing Office, Washington, D.C. 1616pp.

__________________ 1967. Minerals yearbook 1966. Vols. I-II. Metals, Minerals, and Fuels. U.S. Govt. Printing Office, Washington, D.C. 1352pp.

__________________ 1975. Minerals yearbook 1974. Vol. I. Metals, Minerals, and Fuels. U.S. Govt. Printing Office, Washington, D.C. 1451pp.

U.S. Dept. of Agriculture. 1938. Soils and men. Yearbook of Agriculture. U.S. Govt. Printing Office. Washington, D.C. 1232pp.

Williams, A. B. 1936. The composition and dynamics of a beech-maple climax community. Ecol. Monogr. 6:317-408.

Willson, M. F. 1974. Avian community organization and habitat structure. Ecol. 55:1017-1029.

Wingo, A. L. 1949. Virginia's soils and land use. The Baughman Co., Richmond, VA. 323pp.

Yahner, R. C. 1973. Breeding-bird populations on a strip-mined area in a deciduous forest in Campbell County, Tennessee. M.S. Thesis. Univ. Tennessee, Knoxville. 114pp.

Appendix I. Common and scientific names of birds observed within disturbed or marginal study areas of 12 abandoned contour mines in southwest Virginia.

Common name*	Scientific name*
Red tailed Hawk	Buteo jamaicensis
Mourning Dove	Zenaida macroura
Yellow-billed Cuckoo	Coccyzus americanus
Ruby-throated Hummingbird	Archilochus colubris
Common Flicker	Colaptes auratus
Downy Woodpecker	Picoides pubescens
Hairy Woodpecker	Picoides villosus
Pileated Woodpecker	Dryocopus pileatus
Acadian Flycatcher	Empidonax virescens
Eastern Phoebe	Sayornis phoebe
Eastern Wood Pewee	Contopus virens
Great Crested Flycatcher	Myiarchus crinitus
Rough-winged Swallow	Stelgidopteryx ruficollis
Blue Jay	Cyanocitta cristata
Common Crow	Corvus brachyrhynchos
Carolina Chickadee	Parus carolinensis
Tufted Titmouse	Parus bicolor
White-breasted Nuthatch	Sitta carolinensis
Carolina Wren	Thryothorus ludovicianus
Brown Thrasher	Toxostoma rufum
Catbird	Dumetella carolinensis
Eastern Bluebird	Sialia sialis
American Robin	Turdus migratorius
Wood Thrush	Hylocichla mustelina
Blue-gray Gnatcatcher	Polioptila caerulea
Red-eyed Vireo	Vireo olivaceus
White-eyed Vireo	Vireo griseus
Yellow-throated Vireo	Vireo flavifrons
American Redstart	Setophaga ruticilla
Black-and-white Warbler	Mniotilta varia
Black-throated Green Warbler	Dendroica virens
Cerulean Warbler	Dendroica cerulea
Golden-winged Warbler	Vermivora chrysoptera
Hooded Warbler	Wilsonia citrina
Kentucky Warbler	Oporornis formosus
Ovenbird	Seiurus aurocapillus
Prairie Warbler	Dendroica discolor
Worm-eating Warbler	Helmitheros vermivorus
Yellow-breasted Chat	Icteria virens
Brown-headed Cowbird	Molothrus ater
Red-winged Blackbird	Agelaius phoeniceus
Scarlet Tanager	Piranga olivacea
Summer Tanager	Piranga rubra

Appendix I. Common and scientific names of birds observed within disturbed or marginal study areas of 12 abandoned contour mines in southwest Virginia. (Continued)

Common name*	Scientific name*
American Goldfinch	Carduelis tristis
Cardinal	Cardinalis cardinalis
Chipping Sparrow	Spizella passerina
Field Sparrow	Spizella pulilla
Indigo Bunting	Passerina cyanea
Rufous-sided Towhee	Pipilo erythrophthalmus
Song Sparrow	Melospiza melodia

* According to American Ornithologists' Union Committee on Classification and Nomenclature (1957, 1973, 1976).

Appendix II. Numbers of breeding pairs by species and values of population parameters for disturbed areas on 12 abandoned contour mines in southwest Virginia.

Species	Pairs per mine											
	B	F	G	N	E	K	M	P	R	S	Y	Z
Red-tailed Hawk												*
Mourning Dove			1	1								
Yellow-billed Cuckoo				1			1					*
Common Flicker		1			1		1	1				
Downy Woodpecker	1	1			1	1	1		*			
Hairy Woodpecker			1		1		1		1		1	
Pileated Woodpecker	1				1			1			1	
Acadian Flycatcher							1	1	1	1	1	1
Eastern Phoebe	1	1	1	*	1	1	1	1	1			
Eastern Wood Pewee									*			
Great Crested Flycatcher					1						1	
Rough-winged Swallow							1					
Blue Jay	1		1	1			1	1		1		1
Common Crow	*									1		1
Carolina Chickadee	1	1	1	1	1	1	1	1	1	1	1	1
Tufted Titmouse	1	1	1	1	1	2	1	1	1	1	2	2
White-breasted Nuthatch		1			1				*		1	*
Carolina Wren	1	1	1	1	1	1	1	1	1	1	1	1
Brown Thrasher		1		1		*	1	*				
Catbird	*											
Eastern Bluebird							1					
American Robin					1				*			
Wood Thrush									4	1	1	2
Blue-gray Gnatcatcher	1	1		1		1	1	1	1	1		
Red-eyed Vireo	1	1	1	2	2	2	1	6	3	3	3	2
White-eyed Vireo		1	1	1	1	1		1	1	1	*	
Yellow-throated Vireo		1					1		1		1	
American Redstart								1	2	1	1	
Black-and-white Warbler	1		1	1	2	2	2	3	2	1	2	1

Appendix II. Numbers of breeding pairs by species and values of population parameters for disturbed areas on 12 abandoned contour mines in southwest Virginia. (Continued)

Species	Pairs per mine											
	B	F	G	N	E	K	M	P	R	S	Y	Z
Black-throated Green Warb.										1		
Cerulean Warbler					1				2	1	1	
Hooded Warbler	2							1	3	1	2	1
Kentucky Warbler		1				1		1	2		*	1
Ovenbird						1				1	3	2
Prairie Warbler		1	1	1	2	1	1	1				
Worm-eating Warbler									1	1		
Yellow-breasted Chat			1	1	1		1	1	1	1		
Brown-headed Cowbird			1		1	1	*	2		1		
Red-winged Blackbird						*	*					
Scarlet Tanager	2			1	1	3	2	1	1	*		2
Summer Tanager				1	*		1					
American Goldfinch	1	1	1	1	1	1	1			*		
Cardinal		1	1	1	1	1	1	1	1	1	1	1
Chipping Sparrow						1	1			1		
Field Sparrow		1	*	1	1	1	2	1	*			
Indigo Bunting	2	2	2	1	1	2	3	1	1	2	1	2
Rufous-sided Towhee	1	2	1	1	1	1	2	1	2	1		1
Song Sparrow						1						
Breeding species (SD)	15	19	17	20	24	21	27	22	23	23	18	16
Breeding pairs (PD)	18	21	18	21	27	27	33	29	35	26	25	22
Bird sp. diversity (BD)	2.66	2.91	2.81	2.98	3.14	2.97	3.23	2.88	3.04	3.08	2.79	2.71
Observed species (TD)	17	19	18	21	25	23	29	23	28	24	20	19

* Visitor

Appendix III. Numbers of breeding pairs by species and values of population parameters for marginal areas of 12 abandoned contour mines in southwest Virginia.

Species	Pairs per mine											
	B	F	G	N	E	K	M	P	R	S	Y	Z
Red-tailed Hawk							1					
Mourning Dove				1								
Yellow-billed Cuckoo		*		1		*	1	*			*	
Ruby-throated Hummingbird						*						
Common Flicker	1	1	*		1			1				
Downy Woodpecker	1	1	1	1	1	1	1	1		*		
Hairy Woodpecker			1				1		1			
Pileated Woodpecker	1	*			1	*		1	1		1	
Acadian Flycatcher	*							1	1	1	1	1
Eastern Phoebe	1	1	1	1	1	1	1					
Eastern Wood Pewee			1									
Great Crested Flycatcher				*	1		*		*		1	
Blue Jay	1		1	1	*	1	1	1		1		1
Common Crow	*									1		1
Carolina Chickadee	1	1	1	1	1	1		1		1	1	1
Tufted Titmouse	1	1	1	1	1	2	1	2	1	1	2	2
White-breasted Nuthatch	1	1	1	*	1					*	1	
Carolina Wren	1	1	2	1	1	1	1	1	1	1	1	1
Brown Thrasher		1				*	1					
Catbird			*									
Eastern Bluebird			*				1					
American Robin					1							
Wood Thrush	1	1				1	1	1	1		1	1
Blue-gray Gnatcatcher	1	1		1	1	*	1		1			*
Red-eyed Vireo	4	1	3	2	2	4	2	5	2	2	1	1
White-eyed Vireo		1	1	1	1				1		1	
Yellow-throated Vireo	1	1			1	1	2		1	1	2	
American Redstart								1				

Appendix III. Numbers of breeding pairs by species and values of population parameters for marginal areas of 12 abandoned contour mines in southwest Virginia. (Continued)

Species	Pairs per mine											
	B	F	G	N	E	K	M	P	R	S	Y	Z
Black-and-white Warbler	1	1	2	2	2	2	2	1	1	1	2	1
Black-throated Green Warb.										1		
Cerulean Warbler		*	1	*				1	2		1	
Golden-winged Warbler			*									
Hooded Warbler	3	1	1		1	2	2	1	3	1	1	1
Kentucky Warbler	1	1	2		1	2	2	1	2		*	1
Ovenbird	1	1	1			2		1	1			2
Prairie Warbler		1	1	1	1		2					
Worm-eating Warbler	1					1	1	1	1	1		
Yellow-breasted Chat	1		1	1	1		1	1	1	1		*
Brown-headed Cowbird	1		1						2			
Red-winged Blackbird						*						
Scarlet Tanager	2	1	1	1	1	3	3	1	1	1		2
Summer Tanager	*		*	1								
American Goldfinch	1		1			1				*		
Cardinal		1	2		1	1	1	1	1	1	1	1
Indigo Bunting	2	2	2	1	2	1	2		1	2	1	2
Rufous-sided Towhee		2	2	1	1	1	2		2	1		1
Song Sparrow						1						
Breeding species (SM)	23	22	24	18	23	20	24	20	22	17	16	16
Breeding pairs (PM)	30	24	32	20	26	30	34	25	29	19	19	20
Bird sp. diversity (BM)	3.01	3.06	3.10	2.86	3.09	2.88	3.10	2.84	3.01	2.80	2.73	2.72
Observed species (TM)	26	25	29	21	24	26	25	21	23	20	18	18

* Visitor

Appendix IV. Numbers of breeding pairs by species and values of population parameters for total study areas on 12 abandoned contour mines in southwest Virginia.

Species	Pairs per mine											
	B	F	G	N	E	K	M	P	R	S	Y	Z
Red-tailed Hawk							1					*
Mourning Dove			1	1								
Yellow-billed Cuckoo		*		1		*	1	*			*	*
Ruby-throated Hummingbird						*						
Common Flicker	1	1	*		1		1	1				
Downy Woodpecker	1	1	1	1	1	1	1	1	*	*		
Hairy Woodpecker			1		1		1		1	1	1	1
Pileated Woodpecker	1	*			1	*		1	1		1	
Acadian Flycatcher	*						1	1	1	1	1	1
Eastern Phoebe	1	1	1	1	1	1	1	1	1			
Eastern Wood Pewee			1						*			
Great Crested Flycatcher			1	*	1		*		*		1	
Rough-winged Swallow							1					
Blue Jay	1		1	1	*	1	1	1		1		1
Common Crow	*									1		1
Carolina Chickadee	1	1	1	1	1	1	1	1	1	1	1	1
Tufted Titmouse	1	1	1	1	1	2	1	2	1	1	2	2
White-breasted Nuthatch	1	1	1	*	1				*	*	1	*
Carolina Wren	1	1	2	1	1	1	1	1	1	1	1	1
Brown Thrasher		1		1		*	1	*				
Catbird	*		*									
Eastern Bluebird			*				1					
American Robin					1				*			
Wood Thrush	1	1				1	1	1	4	1	1	2
Blue-gray Gnatcatcher	1	1		1	1	*	1	1	1	1		*
Red-eyed Vireo	4	1	3	3	3	4	2	7	3	3	3	2
White-eyed Vireo		1	1	1	1	1		1	1	1	*	
Yellow-throated Vireo	1	1			1	1	2		1	1	2	
American Redstart								1	2	1	1	

Appendix IV. Numbers of breeding pairs by species and values of population parameters for total study areas on 12 abandoned contour mines in southwest Virginia. (Continued)

Species	Pairs per mine											
	B	F	G	N	E	K	M	P	R	S	Y	Z
Black-and-white Warbler	1	1	2	2	2	2	2	3	2	1	2	1
Black-throated Green Warb.										1		
Cerulean Warbler		*	1	*	1			1	2	1	1	
Golden-winged Warbler			*									
Hooded Warbler	3	1	1		1	2	2	1	3		2	
Kentucky Warbler	1	1	2		1	2	2	1	2		*	1
Ovenbird	1	1	1			2		1	1	1	3	2
Prairie Warbler		1	1	1	2	1	2	1				
Worm-eating Warbler	1					1	1	1	1	1		
Yellow-breasted Chat	1		1	1	1		1	1	1	1		*
Brown-headed Cowbird	1		1		1	1			2	1		
Red-winged Blackbird						*	*					
Scarlet Tanager	2	1	1	1	1	3	3	1	1	1	*	2
Summer Tanager	*		*	1	*		1					
American Goldfinch	1	1		*	1	1	1			*		
Cardinal		1	2	1	1	1	1	1	1	1	1	1
Chipping Sparrow						1	1			1		
Field Sparrow		1	*	1	1	1	2	1	*			
Indigo Bunting	2	2	2	1	2	2	3	1	1	2	1	2
Rufous-sided Towhee	1	2	2	1	1	1	2	1	2	1		1
Song Sparrow						1						
Breeding species (ST)	24	24	25	21	28	25	32	27	25	25	18	16
Breeding pairs (PT)	31	26	33	24	33	36	44	36	38	28	26	22
Bird sp. diversity (BT)	3.06	3.15	3.14	2,98	3.27	3.11	3.38	3.08	3.10	3.16	2.79	2.71
Observed species (TT)	28	27	31	25	30	31	34	29	31	28	22	21

* Visitor

Appendix V. Values of vegetation and site-factor variables for 12 disturbed study areas on abandoned contour mines in southwest Virginia.

Mine	Total vegetative cover (%)	Woody cover (%)	Herbaceous cover (%)	Cover 0-1m (%)	Cover 1-4m (%)	Sum of covers 0-4m (%)
B	23.7	19.1	11.1	19.4	16.6	36.0
F	41.4	32.4	17.5	31.8	19.2	51.0
G	23.4	15.4	17.0	20.0	11.4	31.4
N	45.1	35.5	21.5	33.6	29.8	63.4
E	73.3	50.5	57.2	63.3	35.2	98.5
K	62.3	40.9	36.7	48.6	31.3	79.8
M	83.6	46.9	50.4	63.9	32.1	95.9
P	87.9	57.5	55.9	65.4	44.1	109.4
R	90.6	85.7	59.5	63.2	68.9	132.1
S	92.8	89.8	17.5	41.0	68.0	109.0
Y	88.5	81.6	35.5	40.9	58.1	99.0
Z	94.2	84.2	38.7	47.0	46.4	93.4

Mine	Canopy cover (%)	Sum of covers (%)	Cover FHD	Volume 0-1m (%)	Volume 1-4m (%)	Volume 0-4m (%)	Canopy volume (%)
B	6.2	42.1	1.005	15.8	9.2	10.8	0.4
F	18.0	69.0	1.063	25.7	15.7	18.2	1.2
G	4.7	36.1	0.955	15.7	6.7	9.0	1.0
N	27.8	91.2	1.095	19.6	21.4	20.9	10.3
E	29.8	128.2	1.042	54.3	28.8	35.2	9.8
K	22.8	102.6	1.050	23.6	19.4	20.4	3.7
M	27.9	123.9	1.027	49.0	19.2	26.7	2.9
P	28.5	137.9	1.044	51.8	28.3	34.2	6.4
R	71.6	213.7	1.093	30.3	56.5	49.9	32.1
S	68.2	177.2	1.074	37.8	56.9	52.1	33.9
Y	75.4	174.4	1.069	28.1	21.4	23.1	40.9
Z	79.6	172.9	1.064	24.5	38.6	35.0	33.1

Appendix V. Values of vegetation and site-factor variables for 12 disturbed study areas on abandoned contour mines in southwest Virginia. (Continued)

Mine	Total volume (%)	Volume FHD	Stems 0-1m (/100m^2)	Stems 1-2m (/100m^2)	Stems 2-4m (/100m^2)	Stems 1-4m (/100m^2)
B	2.2	0.735	28.7	6.9	3.4	10.3
F	4.0	0.772	23.5	8.9	9.8	18.7
G	2.4	0.765	49.3	5.2	1.9	7.1
N	12.1	1.055	34.5	12.9	4.5	17.4
E	14.0	0.914	36.7	16.1	9.2	25.2
K	6.5	0.912	99.1	11.2	8.4	19.6
M	6.8	0.741	17.4	6.7	6.3	13.1
P	11.0	0.865	73.2	21.6	13.4	35.0
R	35.1	1.055	44.9	6.7	10.0	16.7
S	36.9	1.072	59.5	43.5	9.0	52.5
Y	38.0	1.063	118.0	12.8	16.2	29.0
Z	33.4	1.082	59.2	10.5	10.1	20.6

Mine	Stems 4m-7.6cm DBH (/100m^2)	Stems over 7.6cm DBH (/100m^2)	Stems over 1m (/100m^2)	Stems over 4m (/100m^2)	Total stems (/100m^2)
B	0.8	0.4	11.5	1.2	40.2
F	1.2	0.3	20.2	1.5	43.6
G	0.7	0.1	7.9	0.8	57.2
N	1.4	2.3	21.2	3.8	55.7
E	5.5	0.9	31.6	6.4	68.4
K	4.7	2.4	26.7	7.1	125.7
M	3.5	2.0	18.6	5.6	36.0
P	6.6	1.5	43.1	8.1	116.3
R	7.7	8.5	32.9	16.2	77.8
S	9.4	8.6	70.4	17.9	129.9
Y	15.7	11.0	55.7	26.6	173.6
Z	18.2	8.4	47.2	26.6	106.4

Appendix V. Values of vegetation and site-factor variables for 12 disturbed study areas on abandoned contour mines in southwest Virginia. (Continued)

Mine	Stem index-3	Stem index-4	Stem index-5	Weighted stems 1-4m (/100m^2)	Weighted stems over 1m (/100m^2)	Weighted stems over 4m (/100m^2)
B	0.692	0.959	0.872	24.0	29.0	5.0
F	0.811	0.938	1.124	47.1	53.3	6.2
G	0.447	0.901	0.526	16.1	19.5	3.4
N	0.843	1.057	1.066	39.3	56.8	17.5
E	0.924	1.107	1.203	59.7	86.1	26.5
K	0.639	1.251	0.782	47.6	78.3	30.7
M	1.008	1.291	1.360	32.5	56.7	24.2
P	0.838	1.111	1.071	83.4	117.1	33.7
R	0.974	1.376	1.263	43.4	116.6	73.2
S	0.997	1.085	1.278	114.0	194.3	80.3
Y	0.849	1.374	1.068	74.2	191.8	117.5
Z	0.990	1.339	1.280	51.3	166.0	114.6

Mine	Weighted total stems (/100m^2)	Weighted stem index-3	Weighted stem index-4	Weighted stem index-5	Canopy height (m)	Woody species
B	57.8	0.925	1.137	1.265	3.3	6
F	76.7	0.864	1.006	1.314	6.1	7
G	68.7	0.726	1.086	0.904	3.6	7
N	91.4	1.048	1.256	1.444	7.6	9
E	122,8	1.042	1.233	1.474	8.3	11
K	177.4	0.982	1.353	1.283	5.7	10
M	74.1	1.067	1.362	1.587	8.3	9
P	190.3	1.036	1.244	1.432	8.1	11
R	161.5	1.068	1.317	1.542	15.9	14
S	253.8	1.064	1.284	1.528	17.1	12
Y	309.7	1.078	1.341	1.494	15.6	12
Z	225.2	1.032	1.282	1.521	12.1	11

Appendix V. Values of vegetation and site-factor variables for 12 disturbed study areas on abandoned contour mines in southwest Virginia. (Continued)

Mine	Total cover heterogeneity	Woody cover heterogeneity	Herbaceous cover heterogeneity	Canopy cover heterogeneity	Canopy height heterogeneity-3
B	0.769	0.594	0.541	0.403	0.863
F	0.807	0.818	0.708	0.595	0.920
G	0.687	0.583	0.687	0.324	0.931
N	0.741	0.807	0.640	0.831	0.960
E	0.720	0.864	0.812	0.751	0.727
K	0.901	0.865	0.934	0.649	0.890
M	0.645	0.930	0.899	0.801	0.770
P	0.448	0.890	0.903	0.616	0.707
R	0.361	0.498	0.831	0.482	0.520
S	0.347	0.381	0.671	0.733	0.497
Y	0.520	0.504	0.912	0.714	0.638
Z	0.268	0.485	0.917	0.720	0.586

Mine	Canopy height heterogeneity-5	Heterogeneity index-1	Heterogeneity index-2	Heterogeneity index-3	Age
B	0.721	0.857	0.893	1.035	12
F	0.819	1.345	1.221	1.322	18
G	0.676	0.946	0.687	0.942	11
N	0.825	1.272	1.397	1.532	17
E	0.930	1.605	1.400	1.198	18
K	0.845	1.645	1.395	1.439	17
M	0.929	1.759	1.374	1.215	17
P	0.943	1.735	1.007	0.771	27
R	0.840	1.168	0.682	0.362	18
S	0.531	0.583	0.611	0.577	21
Y	0.842	1.258	1.076	0.872	21
Z	0.731	1.133	0.719	0.574	21

Appendix V. Values of vegetation and site-factor variables for 12 disturbed study areas on abandoned contour mines in southwest Virginia. (Continued)

Mine	Aspect (compass degrees - 180)	Highwall height (m)	Disturbed area width (m)	Undisturbed border (m)	Outslope area (%)
B	22	7.6	63	400	25.4
F	130	27.4	101	345	44.3
G	10	24.4	97	380	42.9
N	15	19.8	105	290	21.7
E	113	15.2	90	360	4.3
K	60	9.1	99	360	7.5
M	135	45.7	100	325	14.0
P	113	19.8	102	340	30.6
R	180	15.2	78	375	40.3
S	22	12.2	89	360	62.2
Y	45	13.7	67	380	44.2
Z	130	18.3	70	375	31.5

BREEDING BIRD POPULATIONS IN RELATION TO THE VEGETATION STRUCTURE OF ABANDONED CONTOUR MINES IN SOUTHWEST VIRGINIA

By

David L. Chapman

(ABSTRACT)

Twelve study areas on abandoned contour mines in southwest Virginia were surveyed to investigate relationships between breeding bird population parameters and structural aspects of the disturbed area vegetation. The territorial mapping method was employed to census bird populations. The number of breeding species, number of breeding pairs, bird species diversity, and number of observed species (breeding or visiting) were determined for each disturbed area, the marginal undisturbed forest, and each total study area (marginal and disturbed areas combined). Vegetation was sampled within units of similar vegetation on each disturbed area; 17 vegetation parameters were recorded for each unit. These were weighted by the size of each vegetation unit and averaged for each disturbed area. Linear and multiple regressions of each population variable were performed on 51 vegetation and site-factor variables.

Bird population parameters of the disturbed and total study areas showed positive relationships with several aspects of disturbed area revegetation. However, among forested orphan mines, decreases in bird populations were observed when canopy closure apparently affected a reduction in understory vegetation. Bird populations of the marginal

areas decreased with the reforestation of the disturbed areas, apparently reflecting a decrease in the edge effect. Several sets of equations for population parameters of the disturbed and total study areas are presented for use in habitat evaluation.

Relationships revealed for bird population parameters of the disturbed and total study areas suggest that reclamation efforts should strive to achieve a high degree of vegetative cover, increase the amount of ground layer vegetation, and provide for the future development of higher vegetational strata. These vegetational features should be introduced in a manner which will augment existing vegetational heterogeneity.