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EFFECTS OF STRIPMINING ON FISH AND DIATOMS IN STREAMS OF THE NEW RIVER DRAINAGE BASIN[1]

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ABSTRACT

Contour mining for coal as has been practiced in the New River drainage basin of East Tennessee profoundly affects population size, species richness, and species equitability of aquatic organisms inhabiting streams draining the mined areas. Fish and diatom communities have been sampled over a three year period from four small watersheds, one undisturbed and three with strip mine acitvity. Diatom species diversity was significantly greater in the control stream where more than twice as many species of diatoms were found than in the mine-disturbed streams. *Semotilus atromaculatus,* the creek chub, composed 95-98% of the fish population in the mined basins. Darters were absent except in the control stream. The trend for both fish and diatoms was toward smaller populations and fewer species of less equitable distribution with increasing mine activity. Changes observed in community structure of organisms in these streams could not be explained by differences in water quality other than those related to increased runoff, sediment load, and siltation caused by mining activity.

INTRODUCTION

As a function of our energy-intensive society and the depletion of more conventional energy reserves, coal mining in the United States is expected to increase by 50-240% over the next seven years (Minear and Tschantz, 1976). Of this increase at least 67% is expected to be taken from strip mines. The need to determine the impact of strip mine operation on the biology of aquatic systems exposed to this increased activity is imperative if adequate protective measures are to be devised. A number of studies have been conducted in our neighboring regions of Kentucky, West Virginia and Pennsylvania (Branson and Batch, 1972, 1974; Plass, 1976; Gang and Langmuir, 1974), but until recently little attention has been paid the coal mining regions of East Tennessee. The New River drainage basin in Anderson, Morgan, Campbell, and Scott counties of Tennessee has lately, however, been the subject of intensive study as a project of the Appalachian Resources Council (Tung, 1975; Tschantz, 1975; Minear and Tschantz, 1976; Minear *et al.*, 1977; Talak, 1977; Tolbert and Vaughan, 1978).

The structures of biological communities in streams change with degraded water quality. Diatom communities, for instance, are usually characterized by large numbers of species in normal, unpolluted streams (Patrick *et al.*, 1954). Pollution reduces the number of species and alters the relative distribution of individuals in the remaining population. Similar relationships are noted in other groups of organisms. This report describes the conditions of fish and diatom communities in three streams in the New River drainage basin exposed to strip mine effluent as compared to a virgin control stream.

STUDY AREA

The New River watershed (Fig. 1) is in the edge of the Cumberland mountains with very rugged terrain and an area of 382 square miles and an average slope of 14°. The area rainfall is greater than 50 inches a year. Strip mine activity began in the early 1940's and more than 5% of the total surface area of the region has been disturbed to date (Tung, 1975). Although there is some acid mine drainage from deep mines and auger holes, the system is largely characterized by alkaline drainage from strip mines (Minear and Tschantz, 1976), especially in the small watersheds. Such alkaline drainage has been observed in similar situations in West Virginia (Plass, 1976).

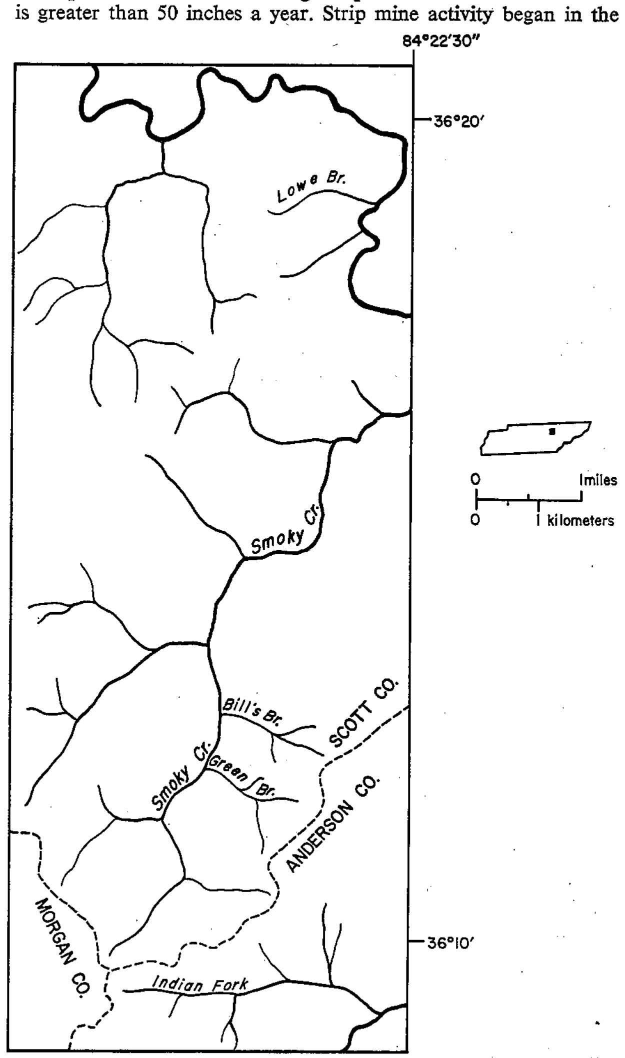

FIG. 1: *Map of New River basin study areas.*

The four streams to be discussed here are Lowe Branch, the undisturbed control, and the mine-disturbed streams, Bills Branch, Green Branch, and Indian Fork. Descriptions of these particular small watersheds with detailed discussion of water quality and chemistry (Minear and Tschantz, 1976), stream hydrology (Tschantz, 1975) and metal movement (Rule, 1975) are available. Information concerning benthic insect communities in these same streams has also been reported (Tolbert and Vaughan, 1978).

Lowe Branch, a first order stream, is 1-2 meters in width and 5-20 cm deep with moderate current. The stream bed is sand overlain with rocks, gravel and organic debris with a 12% average slope. During the late summer, as is common with small undisturbed streams in this area, water flow is intermittent in the stream's lowest reaches.

Indian Fork mining activity began in the 1940's and has continued to the present with 19% of the 1119 hectare watershed disturbed (Minear and Tschantz, 1976). The stream is second order. It is 2-3 meters wide and 5-35 cm deep with moderate to swift current on a slope averaging 8%. The stream bed is of rock and gravel cemented to the substrate with clay, covered with some sand, silt and large amounts of orange-colored iron hydroxide precipitate (yellow boy). The stream margins are of mixed hardwood forest with clearings (human habitation in the lower portions) and mine tailings. Bills Branch, 174 hectares in area, has been disturbed (9%) by strip mining which began in 1974 and lasted through 1975 (Minear and Tschantz, 1976). From 1972 through 1975, 24% of the 357 hectare watershed in Green Branch was similarly disturbed (Minear and Tschantz, 1976). The margins of both these streams are mixed hardwood forest with mine tailings. Large rocks in the stream bed of Bills Branch lie over sand and silt. The rock and gravel in Green Branch are largely cemented to the substrate with clay. In both streams there is a heavy silt-algal deposit on the surface of the rocks.

An extensive survey of chemical and physical parameters of water quality for these same streams during the period of this study has been reported (Minear *et al.*, 1977).

MATERIALS AND METHODS

Fish were captured by means of electric shock from a back-pack battery-operated generator or by seining. Sodium cyanide or the irritant, Cresol, was used to immobilize the fish which then drifted into seines blocking the stream. Neither Cresol nor cyanide proved to be lethal as employed.

Diatoms were collected from glass microscope slides (75 mm x 25 mm) which were left for two-week periods in the streams. This has been established as the optimal length of time for colonization (Patrick *et al.*, 1954). At 3-4 sampling stations per stream groups of 10 slides each were mounted with their long axis vertical in plexiglas slide holders. The slide holders were firmly anchored to the stream bottom so that the top of the slide was not more than 15 cm below the surface of the water. Samples were taken as often as possible over two week intervals from June, 1975 through September of 1976. Material adhering to each slide was scraped into 70% ethanol and centrifuged (800 x g x 10 min). To this pellet was added 10 ml of Chromerge (acid glassware cleaning solution) prepared according to the manufacturer's instructions (Fisher Scientific Company). Suspensions were boiled 20 minutes, cooled, and washed four times by centrifugation in distilled water. Permanent hyrax mounts were made of portions of the remaining material for examination at a magnification of 1000 diameters. The diatoms were identified using the keys provided by Patrick (Patrick *et al.*, 1954) and the U.S. Department of the Interior (1966).

Species diversity for both fishes and diatoms was expressed by the Shannon-Weaver Index (Poole, 1974):

$$H' = (-\sum_{i=1}^{s} p_i \ln p_i) - \frac{(s-1)}{2N},$$

where p is the probability for encountering the i^{th} species, s is the number of species, and n is the total sample size. The Shannon-Weaver index takes into consideration both the number of species and the number of individuals in each and is directly proportional to species diversity. Diatom counts were terminated when the mode of the log normal distribution curve was in the second interval (Hohn, 1961).

Temperature, pH, and oxygen content were regularly measured in each stream at each sampling. Oxygen content was determined with a Yellow Springs Instrument Co. portable oxygen electrode and meter, and pH was measured using an Orion portable pH meter, model 399A.

RESULTS

Shannon-Weaver species diversity indices for diatoms from Lowe's Branch, the unaffected control stream and the three streams subject to runoff from strip mine areas are shown in Table 1. The species diversity, H', for Lowe Branch was always significantly greater ($p < 0.01$) than for the other streams during the same season. In winter the H' dropped but returned to the original value for summer in Lowe Branch. The number of species observed in the strip mine streams was less than half the number found in the control stream in summer. The samples from Indian Fork were uncountable because the quantity of silt adhering to the slide was so great as to obstruct the identification and counting of the few diatoms present. Samples from Green Branch after the summer of 1975 were uncountable for similar reasons. Increased stream flow and turbulence swept the samplers away or completely buried them in silt. When clean samples were obtained from Green Branch, the total number of individuals per slide was reduced by 3-4 orders of magnitude relative to similar slides from Lowe's Branch. Although statistically significant counts of the samples from Green Branch could not be made, the three major genera present, as in Bills Branch, were *Gomphonema, Cymbella,* and *Achnanthes.*

TABLE 1: *Shannon-Weaver index for species diversity of diatoms from four small watersheds in the New River basin*

	Summer '75		Winter '75		Summer '76	
	H'	s	H'	s	H'	s
Lowe Branch	3.4445	(128)	2.7195	(66)	3.550	(110)
Bill's Branch	2.5636	(58)	2.5423	(48)	2.759	(53)
Green Branch	2.4697	(51)	NC		NC	
Indian Fork	NC		NC		NC	

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Diatom community structure can also be represented by fitting a truncated log normal curve to the population-species distribution (Preston, 1948; Patrick *et al.*, 1954). One first counts the number of individuals for each species and then plots the number of species on the ordinant as a function of the number of individuals arranged in logarithmic intervals on the abscissa. Figure 2 shows data plotted in this fashion for a sample collected in July of 1975. The curves shown for Lowe Branch, Bills Branch, and Green Branch are typical of those comparing natural and polluted stream situations (Patrick *et al.*, 1954). The height of the mode, 19.5 for Lowe Branch, is reduced to 8.8 and 7.7 in Bills and Green Branches respectively. With modes of all three curves in the same interval, the curves for Bills and Green Branches are much broader and flatter than the one shown for Lowe Branch. The more sensitive species

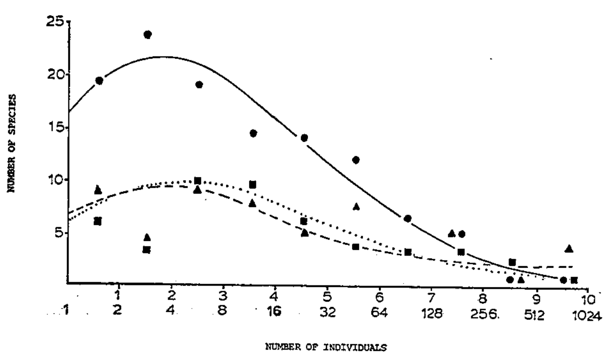

FIG. 2: *Log normal population distribution curves for diatoms from Lowe (●), Bills (■), and Green Branches (▲).*

of diatoms have been eliminated leaving fewer species with more individuals in each. Calculations for the theoretical universe for diatoms (Patrick *et al.*, 1954) predict that a maximum of 162 species may be found in Lowe Branch and 71 and 62 in Bills and Green Branches. It is obvious that species diversity, both in richness and equitability, for diatoms has been greatly reduced in those streams exposed to strip mine activity.

The condition of fish populations in these streams reflects the same changes shown for diatom populations. Table 2 lists the species of fishes captured in Lowe Branch, Bills Branch, Green Branch and Indian Fork. *Semotilus atromaculatus,* the creek chub, composed the largest segment of the population in all streams. In Lowe Branch there were numerous darters, *Etheostoma caeruleum* and *Etheostoma blennioides.* None were found in the stripped streams (with the exception of one individual near the mouth of Bills Branch). Fish populations in the streams affected by strip mines were relatively small. Using capture success as a function of effort expended as a criterion for comparing size of populations, the fish population in Lowe Branch is 6-20 times greater than in Indian Fork, Bills Branch or Green Branch. The species diversity index for fish from Lowe Branch is significantly greater ($p < 0.001$) than for fish from the stripped streams. When Bills Branch, Green Branch and Indian Fork are combined for a composite stripped stream, the species diversity of 0.2041 is significantly lower ($p < 0.001$) than that of Lowe Branch (0.6565) even though the total number of species is greater. The creek chub, *Semotilus atromaculatus,* comprised greater than 98% of the total sample collected from the composite stripped stream relative to 79% from Lowe Branch.

TABLE 2: *Fish species collected from streams in New River watershed*

Lowe Branch	*Campostoma anomalum* *Catostomas commersoni* *Etheostoma blennioides* *Etheostoma caeruleum* *Semotilus atromaculatus*
Bill's Branch	*Campostoma anomalum* *Etheostoma blennioides* *Notropis stramineus* *Semotilus atromaculatus*
Green Branch	*Campostoma anomalum* *Semotilus atromaculatus*
Indian Fork	*Notropis stramineus* *Rhinichthys atratulus* *Semotilus atromaculatus*

There were no systematic or significant variations from stream to stream in temperature or oxygen content. Measurements were made as biological samples were taken. The pH in Lowe's branch was relatively constant at an average of 5.96 (S.D. = 0.59). The pH in Bills and Green Branches was 6.18 (S.D. = 0.51) and 6.31 (S.D. = 0.53) for biweekly measurements over a two year period. The average of pH in Indian Fork with some exposure to acid mine drainage was 6.34 (S.D. = 0.39).

DISCUSSION

So much of the land in the New River watershed is disturbed that finding an unaffected stream is difficult. Lowe Branch is one of the few unspoiled streams large enough to support fish in the area. The flora and fauna of Lowe's Branch, Green Branch, Bills Branch, and Indian Fork were probably similar before mining was initiated in the New River watershed. This is definitely not the case at present. Tolbert and Vaughan (1978) demonstrated that the benthic insect communities in the three streams exposed to strip mine effluent are radically different from the community in Lowe Branch. The disturbed streams showed significant reduction in the number of insect taxa present, population size, and species diversity proportional to the amount of minining disturbance. The same is true of diatom and fish communities. Diatom communities are generally composed of large numbers of species, most of which are represented by a small number of individuals. Changes in water quality may greatly alter the structure

of the community as some species become more common and others are reduced in number or eliminated. More than twice as many diatom species were found in Lowe Branch as in Bills and Green Branches (Table 1). In Green Branch and Indian Fork the diatom population fell so low that statistically accurate counts could not be made. A comparison of the Shannon-Weaver species diversity index for Lowe Branch with diversity indices for the other streams illustrates that Lowe Branch is not only richer in diatom species but that there is a more equitable distribution. The normal disrtibution curves for Lowe, Bills and Green Branches for diatoms give further insight. The mode height of the curve for Lowe Branch is more than twice that for Bills and Green Branches. The curves for Bills and Green are broad and flat: fewer species compose a greater proportion of the population than in Lowe Branch.

Up to 20 times the effort was expended per fish captured in Green Branch, Bills Branch and Indian Fork than that required for similar success in Lowe Branch. *Semotilus atromaculatus,* the creek chub, comprised the majority of samples from all four streams (Table 2). In the disturbed streams, in fact, fish other than creek chubs were rare (2-5% of the total). A surface feeder, the creek chub is not as sensitive to siltation as are bottom feeders such as the darters, *Etheostoma blennioides* and *Etheostoma caeruleum* (Branson and Batch, 1972). No *Etheostoma* were found in Green Branch, or Indian Fork. The stone roller, *Campostoma anomalum,* although preying on diatoms as a bottom feeder, is more tolerant to siltation than darters and maintains a small population in Green and Bills Branches.

Fish species diversity (Table 3) in Lowe Branch is much greater than in the other streams either singly or as a composite ($p < 0.001$). Bills Branch is more diverse than Green Branch ($p < 0.01$) which is more diverse than Indian Fork ($p < 0.01$), the stream with the greatest disturbance in its watershed. As with the diatoms, there are fewer species of less equitable distribution with increasing mine activity in these watersheds.

TABLE 3: *Shannon-Weaver index for species diversity of fishes from four small watersheds in the New River basin*

Location	H'	s	n
Lowe's Branch	0.6565	5	279
Bill's Branch	0.2258	4	206
Green Branch	0.1637	2	177
Indian Fork	0.0830	3	129
Composite stripped	0.2041	6	512

$$H' = \left(-\sum_{i=1} p_i \ln p_i\right) - \frac{(s-1)}{2N},$$

where p = probability for i^{th} species
s = number of species
n = total sample size

In a recent study of the New River and some of its tributaries, Winger (Winger *et al.*, 1977) concluded that the major change in water quality affecting the biology of streams in the New River system was a function of acid mine drainage. In a much more intensive study of Lowe Branch, Bills and Anderson Branch and Indian Fork, others (Minear and Tschantz, 1976; Minear *et al.*, 1977) have concluded that the system is characterized by alkaline mine drainage. All agree, however, that siltation is a problem; in our opinion the principal one. Overton and Minear (1978) have developed a loadograph and pollutograph simulation model which predicts that were Lowe Branch to be disturbed by mining to the same extent as Green Branch, 24%, the load modulus for suspended solids would increase 2000-fold from 4 pounds per acre-inch runoff to 8000 pounds per acre-inch runoff. A rainstorm on March 5, 1976 of similar duration and intensity in Lowe Branch and Bills Branch produced a total sediment load of 575 pounds in Bills Branch relative to 26 pounds in Lowe Branch (Minear *et al.*, 1977). In Green Branch the suspended load was 2,537 pounds. Branson and Batch (1972) concluded that sediment was the factor responsible for attrition in fish populations from an area exposed to acid mine drainage as did Talack (1977) and Tolbert and Vaughan (1978) for insects in the streams of the New River basin. Variations in heavy metals, pH, alkalinity, temperature, oxygen content, and other factors not related to runoff and siltation (Minear *et al.*, 1977) are not sufficient to account for the changes in community structure we have observed for fishes and diatoms in Lowe Branch, Bills Branch, Green Branch, and Indian Fork. We conclude that increase in sediment load and siltation related to strip mine activity is the major factor affecting aquatic communities in the New River system.

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THE DISTRIBUTION OF RUFFED GROUSE IN TENNESSEE

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ABSTRACT

The distribution of ruffed grouse (*Bonasa umbellus*) in Tennessee is generally more restricted than reported 25 years earlier as determined by interviews and recent published records. The western limit of the present range follows the western boundary of the Cumberland Plateau except to extend into Clay, Jackson, and Overton counties. Populations are limited and distributions spotty in most of the Ridge and Valley section.

INTRODUCTION

Ruffed grouse (*Bonasa umbellus*) in Tennessee are near the southern boundary of a range which spans forested areas across the entire North American continent (Johnsgard, 1975). Its generally low numbers and rather secretive nature combine to make difficult an accurate definition of its range in Tennessee. Bump et al. (1947) relied on written correspondence with the Tennessee Department of Conservation when formulating aboriginal and contemporary (1947) range limits for their monograph on ruffed grouse in North America. Schultz (1953) sought to refine this information and provide indexes of regional abundance as part of a state-wide game animal survey conducted for the Tennessee Game and Fish Commission in 1950 and 1951. His methods involved randomly selecting farmers from 15 physiographic regions and interviewing them about wildlife on their farms. To complement this information and offset an inherent bias against wilderness areas, additional detailed interviews were conducted where needed. Finally, county Conservation Officers were questioned on the status of grouse in their respective areas.

The ranges given by Bump et al. (1947) and the counties for which Shultz (1953) reported grouse are shown in Figure 1. Although Schultz did not draw graphical range limits on his own, he described a primary range including the Cumberland Plateau, the upper Tennessee River Valley of East Tennessee, and the Unaka Range. Grouse populations west of this were termed "small" and "isolated." This report updates and revises these earlier works.

METHODS

Five sources of information were utilized: (1) records of drumming censuses, (2) observations published in the Migrant (1960-1976), (3) results of a Game and Fish Commission hunter report survey, (4) locations of grouse collected for a food habits study, and (5) personal communication with various personnel of the Tennessee Wildlife Resources Agency.

RESULTS

From the middle 1950's until 1969, systematic drumming counts were made on wildlife management areas to estimate grouse populations. In morning twilight on 3 days each spring, wildlife officers followed fixed routes and periodically stopped to listen for drumming males. Grouse were heard as recently as 1969 on Fall Creek Falls State Park (Van Buren, Bledsoe Counties) and the following wildlife management areas: Catoosa (Cumberland), Kettlefoot (Johnson), Laurel Fork (Johnson), Ocoee (Polk), Tellico (Monroe) and Unicoi (Unicoi) (Fig. 2). Grouse were recorded drumming on Andrew Johnson W. M. A. (Carter) in 1968.

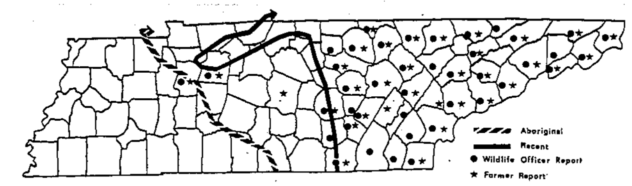

FIG. 1. *Aboriginal range of ruffed grouse in Tennessee as estimated by Bump et al. (1947), and recent range delineated by Schultz (1953) based on reports from farmers and wildlife officers.*

Most of the 130 observations of ruffed grouse recorded in the Migrant during 1960-76 were from areas in which grouse remain common; however, some of the records revealed isolated populations or grouse living in unexpected proximity to urban areas. For example, grouse were observed on Short Mountain in Cannon County (Anon., 1972), on Lookout Mountain in Hamilton County (Anon., 1976), and in Knoxville in Knox County (Anon., 1975) (Fig. 2).

Reports of hunting effort and success are excellent indicators of healthy grouse populations. In both the 1964-1965 and 1965-1966 hunting seasons, cooperating hunters returned hunter report cards to the Tennessee Game and Fish Commission (Legler 1965, 1966). These cards included information detailing hunter effort, grouse flushed and grouse killed. During the 2 seasons, grouse were reported killed in 20 counties and flushed, but not shot, in 1 other (Fig. 2).

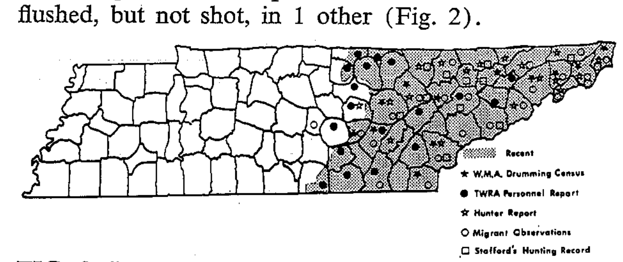

FIG. 2. *Present range of ruffed grouse in Tennessee as defined by this study.*

The locations of grouse shot by hunters were also reported by Stafford (1975) who collected grouse crops from hunters for a recent food habits study. He obtained 151 crops from grouse killed in 14 counties for the period October-February 1972-74; 17 others shot during the 1969-70 season were also used (Fig. 2).

County wildlife officers and biologists of the Tennessee Wildlife Resources Agency were contacted by telephone in August 1977. Their cooperation in providing information based on years of personal experience were an invaluable aid in the preparation of this report. Attention was centered on the counties along the western edge of the Cumberland Plateau and on the counties situated in the eastern loop of the Tennessee River Valley. The western limit of grouse range was reported not to extend beyond the Cumberland Plateau in these counties (reading north to south): Putnam, Cumberland, White, Warren, Grundy, and Franklin (Fig. 2). Farther north, grouse occur west of the plateau, and have been observed as recently as 1972 in Clay, Pickett (Byrdstown area), Jackson, and Overton (in Standing Stone Forest and W. M. A.) counties.

Grouse are rare in the lower valley counties of east Tennessee. No birds were reported from either Loudon, Meigs, or Bradley county. In Rhea, McMinn, and Hamilton counties, reports of grouse were restricted to the mountains and ridges surrounding the valley. In the middle valley counties, grouse are primarily restricted to the ridges also, but ridges are more plentiful there. Grouse were reported to occur in the following locations for these counties: Hamblen—ridges along Cherokee Lake, Bays Mtn.; Jefferson—Bays Mtn., Chestnut Hill area; Knox—House Mtn., Knoxville; and Roane—Pine Ridge, ridges along Watts Bar Lake (Fig. 2). In upper valley counties grouse are comparatively common at all elevations.

DISCUSSION

The aboriginal range given by Bump et al. (1947) was delineated primarily by connecting distributions determined for adjoining states. Grouse occurred in the Western Highland Rim area as late as the 1940's and the original range may have extended somewhat west of this. The 1947 range given by Bump et al. (1947) does not seem reasonable in some details when compared with the data given by Schultz (1953).

The current distribution of the ruffed grouse in Tennessee differs in two respects from that previously delineated: (1) grouse are reported slightly farther west in Franklin County, and (2) the present range is much more restricted than the one given by Schultz in 1953. The population in Franklin County likely does not represent a range extension. Rather, these birds were probably missed in earlier surveys. Many small pockets of grouse have probably been overlooked in the east Tennessee Valley. A few birds may still survive west of the plateau in the eastern Highland Rim.

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