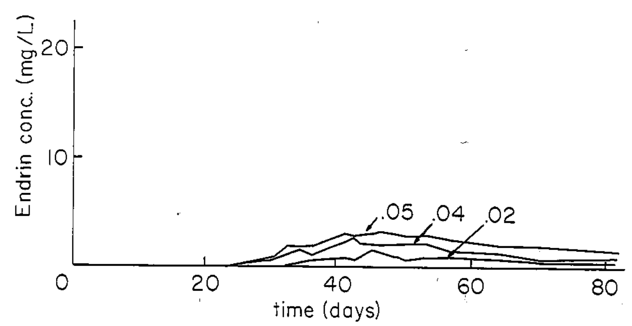

Figure 3. Elution curves for endrin with ethanol-water permeants, mole fraction of ethanol=.02, .04, and .05 as indicated.

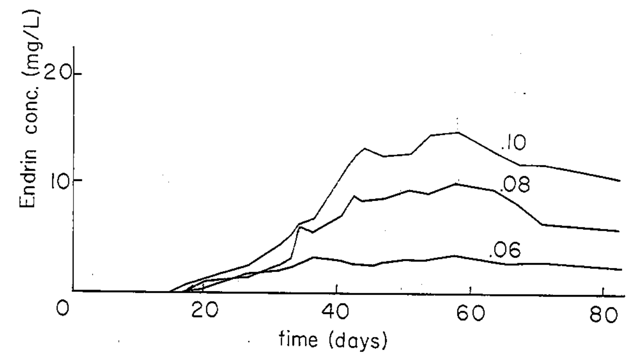

Figure 4. Elution curves for endrin with ethanol-water permeants, mole fraction of ethanol=.06, .08, and .10 as indicated.

PCBs, chlorinated benzenes, and polynuclear aromatic hydrocarbons. This increase in the mobilities of these toxic hydrophobic organic compounds in the presence of water containing organic solvents represents a synergistic effect which markedly increases the risk associated with these compounds. This factor should be taken into account in the prioritization of hazardous waste sites for remedial action.

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AGE, GROWTH, AND SUMMER FOODS OF FOUR CENTRARCHID SPECIES IN A BIG SOUTH FORK NATIONAL RIVER AND RECREATION AREA STREAM FISH COMMUNITY

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ABSTRACT

Age structure, growth, and summer food habits were determined for populations of rock bass *(Ambloplites rupestris)*, longear sunfish *(Lepomis megalotis)*, smallmouth bass *(Micropterus dolomieui)*, and spotted bass *(Micropterus punctulatus)* in a Big South Fork National River and Recreation Area stream, Station Camp Creek. Relatively cool water temperatures, short growing seasons, low benthic macroinvertebrate densities, and low prey fish abundance contributed to growth and longevity characteristics that were comparable to slow growing, more northern-latitude populations. Food habits were similar to those reported for other populations of these species in the southeast. Water was generally of high quality, although low alkalinity and occasional low pH indicated acid sensitivity. The stream contained a rich assemblage of fish species, including species indicative of high quality water.

INTRODUCTION

Growth characteristics, age structure, and trophic relationships have been described for populations of rock bass *(Ambloplites rupestris)*, longear sunfish *(Lepomis megalotis)*, smallmouth bass *(Micropterus dolomieui)*, and spotted bass *(Micropterus punctulatus)*, in other Tennessee and Kentucky streams (Charles, 1957; Benson, 1959; Spier, 1969; Cathey, 1973; Gwinner, 1973; Whittinghill, 1973; and Carlander, 1977); however there are no such published data concerning populations within the Big South Fork National River and Recreation Area (BSFNRRA). The purpose of this paper is to provide analyses of age structures, growth rates, population assemblages, and summer foods of these four centrarchid species in a BSFNRRA stream. These baseline data will be useful in the development of future fisheries management strategies for the BSFNRRA.

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STUDY AREA

Station Camp Creek is a fourth-order stream that flows eastward about 9.3 km from the headwaters at an elevation of about 335 m to its confluence with the Big South Fork of the Cumberland River at an elevation of 253 m (Figure 1). The stream drains a watershed of 8,288 hectares. Terrain surrounding the stream is characterized by a rapid increase in elevation from stream bed to adjacent ridge tops. Vegetation on the slopes is primarily oak-hickory forest, and riparian vegetation is dominated by hemlock and rhododendron. Several small open areas in various stages of succession also occur along the stream.

Three sites were established for the collection of water quality, benthic macroinvertebrate, and fish population samples. The upper reach site was located near the mouth of Charit Creek, the middle reach site was located about 6.0 km downstream from Charit Creek, and the lower reach site was located about 0.2 km upstream of the confluence with Laurel Fork of Station Camp Creek (Figure 1). Substrate of the stream bed at all sites consisted of patches of sand, gravel, cobble, and bedrock. Undercut banks, log jams, and large boulders offered habitat variety throughout the stream.

The BSFNRRA is located in a humid climatic region with mild winters and moist, warm-to-hot summers. Mean seasonal air temperatures on the Plateau are 4.5° C in winter, 13.0° C in spring, 22.5° C in summer, and 13.5° C in fall (Hubbard et al., 1950). Mean annual air temperature is 13.2° C, with 179 frost-free days.

METHODS

Physical and chemical characteristics of the stream were generally sampled monthly at each site during 1982 and 1983. Dissolved oxygen, conductivity, and water temperature were determined by use of YSI electronic meters, and pH was measured with a Model 107 Analytical Measurements, Inc. portable pH meter. Total alkalinity was determined using an endpoint of pH 4.5 with 0.01 N titrant, and calculated according to Lind (1974).

Benthic macroinvertebrate density was determined from three Surber samples taken in riffle habitat of each site in March 1983

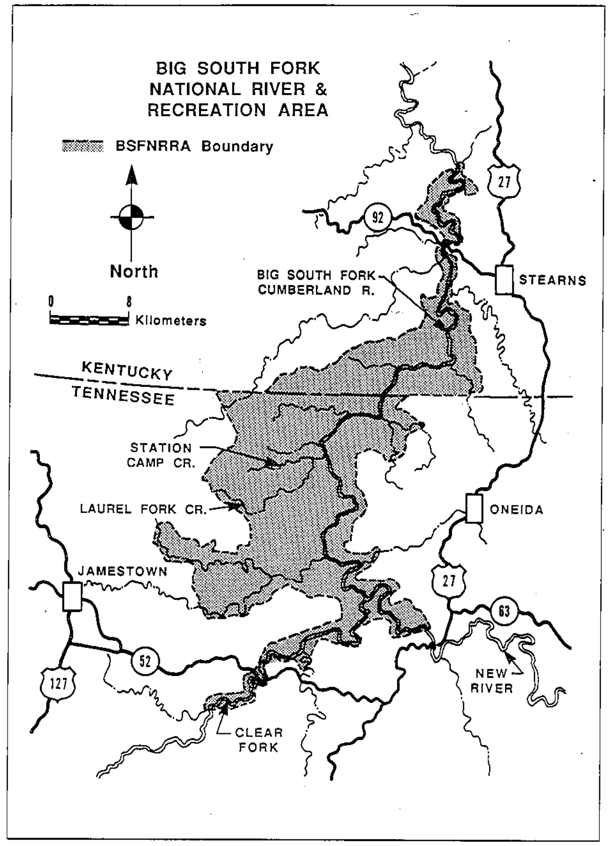

Figure 1. Map of the Big South Fork National River and Recreation Area, indicating location of Station Camp Creek.

and October 1983. Samples were placed in ziplock bags with 10% formalin for subsequent sorting, identification, and enumeration in the laboratory.

Fish community composition was quantified by use of standardized 1.5 hr electrofishing samples at each site in November 1981, April 1982, October 1982, March 1983, October 1983, and March 1984. A sampling team consisted of three people, one who carried the backpack electroshocker and two who dip-netted stunned fish. Riffles, pools, and runs were sampled with equal amounts of time; and no extra effort was exerted to capture particular fish. Fish were returned to the stream after sorting, identification, and enumeration. Total and standard lengths to the nearest mm, weights to the nearest gram, and scale samples were taken from sport fish species prior to their release.

To obtain stomach content samples from sport fish species, the stream was sampled on four dates (June 3, June 29, July 18, and August 18) during 1983. On each date, alternating 100-m stream sections were sampled so that the entire stream could be traversed in one day. Stomach contents were extracted using plastic or glass tubes as described by Van Den Avyle and Roussel (1980). Occasionally a pair of long forceps was used to extract crayfish. Stomach contents were placed in ziplock bags with 10% formalin for subsequent laboratory analyses. A small number of fish were sacrificed for otolith samples.

Centrarchid scales were impressed on cellulose acetate slides and viewed on a scale projector. A randomly-selected sample of 18 rock bass and smallmouth bass otoliths were used to assist in the interpretation of scales. All scale samples were read at least twice by two individuals. Scales were read again if any disagreements occurred. Scale annuli were usually distinct and easily discernible. The Fraser or Lee Method was used to calculate total length at each annulus (Carlander, 1977), with literature intercept values of 32 mm used for rock bass (Rector, 1983), 22 mm for longear sunfish (Bettoli, 1979), 32 mm for smallmouth bass (Everhart, 1949), and 24 mm for spotted bass (Bettoli, 1979). Food organisms were identified to order and categorized as aquatic or terrestrial. Blotted wet weight of each food type was recorded to the nearest 0.001 g. The relative importance index of George and Hadley (1979) was calculated for each food type. This index combines the percent frequency of occurrence, the percent total number, and the percent total weight for each food type.

RESULTS AND DISCUSSION

Optimal growth of centrarchids occurs above 25.0° C (Lemke, 1977; Wrenn, 1980; Coutant and DeAngelis, 1983), and growth slows when water temperatures are lower than 13.0° C (Bennett, 1971, p. 102). In Station Camp Creek, there were about six months during which water temperatures were over 13.0° C and water temperatures never exceeded 25.0° C (Table 1). Aquatic ecosystems having total alkalinities above 50 mg/L are usually productive systems (Stickney 1979). Total alkalinity in Station Camp Creek ranged from 1 to 30 mg/L indicating low potential productivity.

Table 1. Physical and chemical characteristics at each sampling site on Station Camp Creek, 1982-1983.

Parameters	Upper Reaches	Middle Reaches	Lower Reaches
Mean width (m)	14.9	16.5	17.1
Mean gradient (m/km)	3.0	8.8	23.0
Water temperature (°C)[a]			
Jan	—	—	6.3(0)1
Feb	4.8(0.3)3	5.0(0)2	4.0(0)1
Mar	9.0(0)1	—	10.5(0)1
Apr	8.4(0.8)2	6.0(0)1	7.9(0.1)2
May	14.5(2.4)2	16.4(2.3)2	13.4(4.5)2
June	18.0(1.8)2	15.9(5.5)2	19.0(0.6)2
July	20.3(0.3)2	23.0(0)1	20.2(1.9)2
Aug	21.5(1.1)2	22.2(0)1	22.8(1.0)2
Sept	21.6(0)1	—	23.0(0)1
Oct	12.6(2.3)3	11.0(5.7)2	12.8(2.9)3
Nov	10.9(3.2)2	12.5(0)1	13.5(0)1
Dec	5.2(0)1	—	—
Dissolved oxygen range (mg/L)	7.5-12.8	8.4-12.1	7.8-13.3
pH range	6.0- 7.6	6.0- 7.5	6.1- 7.5
Total alkalinity range (mg/L)	7-30	1-22	1-30
Conductivity range (umhos/cm3)	29-65	28-55	23-60

[a]Mean (standard deviation) number of days sampled.

Conductivity was also low, revealing low levels of dissolved solids. Dissolved oxygen concentrations were within favorable levels for both warmwater and coldwater fishes throughout the year. Occasional low pH levels, along with the low buffering capacity (low alkalinity), indicated a sensitivity to acid precipitation in this stream.

Benthic macroinvertebrate densities (Table 2) were similar to the low densities (mean densities of 241 to 724 organisms · m-2) reported for other infertile southern Appalachian streams (Cada et al., 1987). Mean benthic macroinvertebrate densities in more productive north-central Tennessee streams were 4803 organisms · m^{-2} in Spring Creek (Smith, 1978), 1541 · m-2 in New River (Lokey, 1979), 2964 · m-2 in Clear Fork (Lokey, 1979), and 1262 · m-2 in Blackburn Fork (Baker, 1983). The relatively low densities of benthic macroinvertebrates in Station Camp Creek reflect the low production potential indicated by alkalinity and conductivity levels.

A total of 32 fish species were collected from Station Camp Creek (Table 3), indicating a diverse fish fauna for a fourth-order stream. Species richness increased from 23 species in the upper reaches to 30 in the lower reaches. There were generally low abundances of prey species for the piscivorous centrarchids, with

Table 2. Density (number · M-2) of major macroinvertebrate taxa and total density at each sample site of Station Camp Creek, March 1983 and October 1983.

Taxon	Upper Reaches March	Upper Reaches October	Middle Reaches March	Middle Reaches October	Lower Reaches March	Lower Reaches October
Diptera	466	180	477	118	362	190
Ephemeroptera	75	294	175	420	54	520
Trichoptera	7	175	14	86	0	513
Coleoptera	0	154	11	32	11	183
Plecoptera	100	32	47	32	50	36
Oligochaeta	36	11	18	4	0	22
Decapoda	0	0	0	4	0	4
Other Taxa	7	18	14	14	11	11
Total Density	690	664	756	710	488	1479

Table 3. Number of fish per electrofishing hour in Station Camp Creek, 1981-1984. A total of nine hours of electrofishing was employed at each site.

	Number per Electrofishing Hour		
	Upper Reaches	Middle Reaches	Lower Reaches
Petromyzontidae			
Allegheny brook lamprey			
Ichthyomyzon greeleyi			0.1
Salmonidae			
Rainbow trout			
Oncorhynchus mykiss	1.8	0.3	0.1
Brown trout			
Salmo trutta			0.1
Cyprinidae			

Table 3 continued

	Number per Electrofishing Hour		
	Upper Reaches	Middle Reaches	Lower Reaches
Central stoneroller			
Campostoma anomalum	81.0	59.0	60.0
River chub			
Nocomis micropogon			0.1
Rosefin shiner			
Notropis ardens	9.7	12.3	0.1
Striped shiner			
N. chrysocephalus		0.1	
Whitetail shiner			
N. galacturus			0.3
Rosyface shiner			
N. rubellus			23.7
Spotfin shiner			
N. spilopterus		0.1	
Sand shiner			
N. stramineus	1.1	10.6	1.9
Telescope shiner			
N. telescopus	36.3	70.3	47.1
Sawfin shiner			
N. sp.	1.3	3.0	0.1
Mimic shiner			
N. volucellus		0.1	
Creek chub			
Semotilus atromaculatus	10.8	2.7	1.7
Catostomidae			
White sucker			
Catostomus commersoni	0.1	0.8	0.3
Northern hog sucker			
Hypentelium nigricans	12.2	20.0	10.9
Black redhorse			
Moxostoma duquesnei	0.1	0.2	0.3
Ictaluridae			
Stonecat			
Noturus flavus	0.1	0.2	0.6
Centrarchidae			
Rock bass			
Ambloplites rupestris	1.4	2.3	1.8
Bluegill			
Lepomis macrochirus	0.1	0.2	0.2
Longear sunfish			
L. megalotis	0.1	0.8	1.3
Smallmouth bass			
Micropterus dolomieui	1.6	1.9	0.4
Spotted bass			
M. punctulatus	0.6	0.1	1.4
Percidae			
Emerald darter			
Etheostoma baileyi	0.1	0.8	
Greenside darter			
E. blennioides	4.9	3.9	4.8
Rainbow darter			
E. caeruleum	20.4	12.6	15.7
Bluebreast darter			
E. camurum	0.3	0.9	2.1
Ashy darter			
E. cinereum	0.3	0.9	0.2
Spotted darter			
E. maculatum	0.1	0.2	2.2
Speckled darter			
E. stigmaeum	0.7	1.6	
Logperch			
Percina caprodes	1.2	1.1	

stonerollers *(Campostoma anomalum)* and telescope shiners *(Notropis telescopus)* being most abundant. Centrarchid species and most percid species were in very low abundance. The presence of rainbow trout *(Oncorhynchus mykiss)* and brown trout *(Salmo trutta)* from earlier stockings, along with a diverse assemblage of cyprinids and percids, indicated relatively high quality water.

There was no significant difference (General Linear Model, $P>0.05$) in centrarchid growth rates among different stream sections and years; therefore, data from the entire stream and the four years were combined (Table 4). The growth of each species was generally slower than that reported for other streams in Tennessee and Kentucky (Table 5). In 52 of 63 comparisons of total length at annulus, Station Camp Creek fish were smaller. Maximum age of each species was generally greater than ages determined for other stream populations in Tennessee and Kentucky (Table 5), and more similar to maximum ages found in populations at more northern latitudes (Carlander, 1977). This age structure is to be expected because slower growing individuals tend to live longer than their faster growing allopatric counterparts (Moyle and Cech, 1988). Annuli for the current year were not visible on scales until May, and completion of annulus formation for the population occurred between July and August. This pattern of annulus formation indicates an onset of active feeding and growth comparable to that occurring in relatively cooler waters and at more northern latitudes (Regier, 1962).

Table 4. Age and mean calculated total length at each annulus of 212 rock bass, 106 longear sunfish, 144 smallmouth bass, and 38 spotted bass collected from Station Camp Creek, 1981-1984.

Species	Weighted mean total length (mm) at each annulus and sample size at each annulus											
	1	2	3	4	5	6	7	8	9	10	11	12
Rock bass												
Length	50	76	103	130	150	169	184	200	209	236	246	261
Sample size	212	197	186	167	120	88	37	14	10	5	4	3
Longear sunfish												
Length	43	61	81	99	114	121	124	116	128	135		
Sample size	106	74	46	29	10	4	3	1	1	1		
Smallmouth bass												
Length	71	104	145	179	203	219	238	226	196			
Sample size	144	108	83	56	36	18	5	2	1			
Spotted bass												
Length	59	85	114	151	190	213	248					
Sample size	38	34	33	30	19	9	5					

Table 5. Age and mean calculated total length at each annulus of rock bass, longear sunfish, smallmouth bass, and spotted bass in various Tennessee and Kentucky streams.

Species and Location	Mean total length (mm) at each annulus								Reference
	1	2	3	4	5	6	7	8	
Rock bass									
Elk River, TN	76	155	211						Benson, 1959
Spring Creek, TN	35	65	101	156	183	195			Spier, 1969
Obed River, TN	43	77	111	147	165	185			Spier, 1969
Spring Creek, TN	45	81	115	162	194				Gwinner, 1973
Roaring River, TN	55	86	113	142	180	207			Cathey, 1973
Longear sunfish									
Kentucky streams	66	107	135	150					Carlander, 1973
New River, TN	43	69	88	103	101				Bettoli, 1979
Smallmouth bass									
Spring Creek, TN	45	90	118	165	199				Gwinner, 1973
Roaring River, TN	95	186	267	355	435				Cathey, 1973
Cumberland River, TN	121	218	275	333	373	400			Whittinghill, 1973
Spotted bass									
Floyd's Fork Creek, KY	97	107	231	254	312				Charles, 1957
Cumberland River, TN	115	203	308	383					Whittinghill, 1973
New River, TN	72	137	183	230	245				Bettoli, 1979

Crayfish were the most important food in the diet of rock bass, smallmouth bass, and spotted bass (Table 6). The remainder of the diet of these species was fish and a combination of aquatic and terrestrial invertebrates. Even though rock bass as small as 101 mm ate crayfish, the importance of crayfish increased with rock bass size. Keast (1977) reported a similar pattern, with rock bass of all size classes tending to take food of the largest size that could be swallowed.

The diets of smallmouth bass and spotted bass were similar to those of rock bass, but fish were more important in their diets (Table 6). Fish were found in the stomachs of the smallest smallmouth bass (112 mm) and the smallest spotted bass (109 mm) sampled. As was the case in previous studies (Hodson and Strawn, 1969; Aggus, 1973), bass appeared to eat food organisms in relation to their abundance and vulnerability (Tables 2 and 3); however, there seemed to be some selection for crayfish. The importance of aquatic insects in the diet of smallmouth bass, as occurred in our study, has also been previously reported (Applegate et al., 1967; Austen and Orth, 1985).

The longear sunfish is usually classified as an insectivore, but is also known to eat other small invertebrates and an occasional small fish (Pflieger, 1975). Applegate et al. (1967) found that longear sunfish over 100 mm in length relied heavily on terrestrial insects. Longear sunfish examined during this investigation did

Table 6. Relative importance indices (%) of the food items in the diets of four centrarchid species in Station Camp Creek, BSFNRRA, June-August 1983. A = aquatic organisms; T = terrestrial organisms.

Food	Fish species (number with food; total length range, mm)[a]			
	Rock bass (51;90-224)	Longear sunfish (10;102-224)	Smallmouth bass (42;112-248)	Spotted bass (5;109-300)
Diptera, fly				
Larvae, A	1.1		1.1	
Adult, T	2.6	2.0	3.6	
Ephemeroptera, mayfly				
Larvae, A	13.6	29.0	8.0	6.1
Adult, T			1.0	12.3
Trichoptera, caddisfly				
Adult, T		2.2	0.5	
Coleoptera, beetle				
Larvae, A			1.1	
Adult, T	2.5	2.7	0.9	
Plecoptera, stonefly				
Larvae, A		11.2		
Adult, T		0.5		
Oligochaeta, earthworm				
Adult, T		11.5		
Arachnida, spider				
Adult, T	2.3		4.1	3.4
Orthoptera, grasshopper				
Adult, T			0.6	
Hymenoptera, bee				
Adult, T		2.2		
Homoptera, leafhopper				
Adult, T	0.5		1.0	
Lepidoptera, moth				
Non-adults, T	8.9	21.3	12.3	14.1
Megaloptera, alderfly				
Larvae, A	1.0			
Odonata, dragonfly				
Larvae, A	1.3		0.8	
Chironomidae, midge				
Larvae, A	1.0	17.9		
Decapoda, crayfish				
Adult, A	61.3		51.0	46.5
Cyprinidae, minnow				
Adult, A	3.9		13.5	17.6

[a] The percentage of the total sample of longear sunfish, rock bass, smallmouth bass, and spotted bass with empty stomachs was 67, 62, 37, and 20.

not consume crayfish or fish, but relied on aquatic and terrestrial insects.

CONCLUSIONS

Rock bass, longear sunfish, smallmouth bass, and spotted bass exhibited dietary habits characteristic of each species, but relative growth rates were slow and longevity greater. Even though water quality conditions indicated relatively low production potential and acid sensitivity, there was a rich diversity of fish species present; however, most species were not abundant. Benthic macroinvertebrate densities were also relatively low, and low food abundance may contribute to slow growth rates of centrarchids. Cool water temperatures and short growing seasons may also be factors related to these growth and longevity characteristics that are similar to those of populations at more northern latitudes. Because the centrarchids are so slow growing, these populations may not adequately support increases in angler exploitation rates. This study should be repeated at some future time to monitor changes that may occur as this recreation area continues to develop.

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PREY CONSUMED BY BARN OWLS, *TYTO ALBA,* IN CLAIBORNE COUNTY, TENNESSEE

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ABSTRACT

One hundred twenty-six barn owl *(Tyto alba)* pellets were collected from two roosts in Claiborne County, Tennessee. A total of 291 prey animals were identified from skeletal remains. Mammals accounted for 97.6% of the prey consumed. *Synaptomys cooperi, Blarina brevicauda,* and *Sigmodon hispidus* were the most frequently occurring taxa. *Cryptotis parva* was a prominent prey at one roost. The finding of a least weasel *(Mustela nivalis)* skull and the subsequent capture of two specimens suggest a viable population of this species.

INTRODUCTION

In recent years, concern has developed over the decline of barn owl *(Tyto alba)* populations. Changes in land management and farming practices which reduce grassland or meadow habitat adversely affect barn owl populations (Colvin 1985, 1986). The barn owl is considered a rare to uncommon resident within Tennessee (Alsop 1980). Concern for this species has prompted the Tennessee Wildlife Resources Agency to request that citizens report roost sites.

Information concerning prey taken by barn owls in Tennessee is limited. Smith *et al.* (1974) reported finding hairy-tailed mole *(Parascalops breweri),* star-nosed mole *(Condylura cristata),* and eastern harvest mouse *(Reithrodontomys humulis),* remains in the pellets of barn owls found in Johnson and Washington counties. In the Nashville area, Simpson and Jamison (1942) found the skulls of "small rodents" and a "freshly killed cotton rat" in a barn owl nest and at Franklin they found a "meadow mouse and a rat" on the ground below a nest. Jamison and Simpson (1940) after sampling nests and "lots of pellets" state that "barn owls only ate birds very much when the ground was covered with snow ... food at other times consisted almost entirely of small mammals, mostly moles." However, these investigators did not report on species of birds and mammals taken.

Because of the limited information on prey taken by barn owls in Tennessee, we analyzed skeletal remains found in regurgitated pellets. Animals remains identified from these pellets provide a record of barn owl prey taken in East Tennessee.

METHODS

Regurgitated pellets were collected from two roosts in Claiborne County. One was in the community of Harrogate and the second in the community of Speedwell. Roosts were located in barns approximately eight miles apart. Eyewitness accounts and feathers at the two sites confirmed the pellets were deposited by barn owls. Pellets were collected monthly from February 1988 through May 1988 and May and June 1989 at the Speedwell roost. At the Harrogate roost pellets were collected only in February and May of 1988 as this roost had either been abandoned or the single owl known to roost at this site had died. One hundred twenty-six pellets (eighty-six complete and forty partial) were gathered from the roosts. Complete pellets were weighed to the nearest tenth gram and the length and width was recorded. Pellets were picked apart with forceps. Animal remains were identified using the criteria of Glass (1951), Whitaker (1968), and Caldwell and Bryan (1982) and by comparison with museum specimens.

RESULTS AND DISCUSSION

The majority of pellets, n=92, were collected during February 1988 and are believed to have been deposited during the spring and summer 1987 because they were dry, gray in color, and loosely held together. In the wild, barn owl pellets are badly weathered after two months and usually after ten months no whole pellets are left (Marti 1974). However, because these pellets were deposited in barns they were not exposed to precipitation and thus may have remained intact longer. Carpet and cloth moth larvae (Lepidoptera: Tineidae) are known to destroy owl pellets (Moon 1940), and in fact, *Tinea* larvae, cases and feces were found in 61%, n=56, of these pellets. Fresh pellets, those left between collections, were dark in color, compact, and several had a glistening mucus coating.

Pellets averaged 46.3 mm in length, 30.8 mm in width and 5.5 g in weight. Moon (1940) reported barn owl pellets to average 7.1 g in western Kansas. The Claiborne County pellets may have averaged less because of the destruction of hair by *Tinea* larvae.

A total of 291 prey items were identified from the 126 pellets. Ten and fifteen taxa were represented in the Harrogate and Speedwell roosts respectively (Table 1). Mammalian prey accounted