THE DISTRIBUTION AND STATUS OF THE FLATTENED MUSK TURTLE, *STERNOTHERUS DEPRESSUS* (TESTUDINES: KINOSTERNIDAE)

CARL H. ERNST
DEPT. OF BIOLOGY, GEORGE MASON UNIVERSITY, FAIRFAX, VIRGINIA 22030

WILLIAM A. COX
DEPT. OF BIOLOGY, MARION MILITARY INSTITUTE, MARION, ALABAMA 36756

KEN R. MARION
DEPT. OF BIOLOGY, UNIVERSITY OF ALABAMA AT BIRMINGHAM, BIRMINGHAM, ALABAMA 35294

Abstract

A survey of the distribution and local population densities of the flattened musk turtle, *Sternotherus depressus*, was conducted in the Black Warrior River drainage of Alabama in 1983. A total of 577 *S. depressus* was collected at 36 (53%) of the 68 sites sampled; 18 (26%) sites had moderate to high density populations, and 8 (12%) other sites supported populations regarded as between low to moderate in density. One 1.6 km stretch in the Sipsey Fork, Bankhead National Forest, Winston County, supported the highest density population yet recorded: 237 *S. depressus* were collected in 3 days. Several of the sites from which the animal previously was reported to have been extirpated or absent produced specimens during the present study. Extensive sand deposits were a major physical component of most of the high density sites, contrary to what has been considered optimal *S. depressus* habitat. Major threats to the species were determined to be agricultural influence, surface mining, forestry practices, commercial collecting, and municipal and industrial pollution. State legislation (1984) now prohibits collection other than by permit for scientific study. Because population numbers are low or appear to be declining across large portions of the species' range (including habitats formerly occupied), we conclude that the status of *S. depressus* should be monitored. However, we believe that the available evidence, including the recent discovery of several high density populations in the northern part of the range, does not support a threatened or endangered listing at the time of this writing. Additional observations on habitat, daily activity patterns, predation and health are also presented.

Introduction

The flattened musk turtle, *Sternotherus depressus*, was described by Tinkle and Webb (1955) on the basis of specimens collected "in the Mulberry Fork of the Black Warrior River, 9 miles east of Jasper, Walker County, Alabama, near the bridge crossing of U.S. highway 78—a sluggish tributary of the Black Warrior River." Since then *S. depressus* has been collected by scientists only sporadically, and its geographical range has been determined to be permanent streams of the Black Warrior River system above the Fall Line (Iverson, 1977). Thus, its entire range lies within Alabama and, more importantly, within the Warrior Coal Basin. The secretive nocturnal nature, restricted range, reported commercial exploitation in recent years, and general lack of information regarding this turtle have led some conservationists and herpetologists to question the overall population status of the turtle and its chances of continued survival (Iverson, 1977; Mount, 1975, 1981). Within the range of the flattened musk turtle extensive surface mining, forestry, and agriculture occur, and several of the major streams have been impounded. Iverson (1977) thought that elimination of fast water environments by impounding was detrimental, and Mount (1981) suggested that acid runoff from mines and siltation from mining, logging and agriculture have been harmful to the turtle. Unfortunately, little is known regarding the basic biology of *S. depressus* or the status of existing populations. Studies on the species' biology and distribution are limited to those of Tinkle and Webb (1955), Tinkle (1958), Estridge (1970), Close (1982) and Mount (1981).

The Office of Endangered Species, United States Fish and Wildlife Service, in 1981 contracted Dr. Robert H. Mount, Auburn University, to determine the status of the flattened musk turtle. In his report, Mount (1981:80-81) concluded that "(1) *depressus* has probably been extirpated from about 220 miles of its former stream habitat; (2) about 101 miles of habitat have been degraded to the extent that the probability of *depressus* occurring and/or being able to maintain viable populations within it is very low; (3) about 349 miles of habitat are marginal in supportive capacity, and that while *depressus* may now occur, its ability to survive under the current conditions ranges from questionable to doubtful; and (4) about 142 miles of free-flowing stream habitat are of sufficiently high quality to continue to support healthy, viable populations of *depressus*." According to Mount (1981:81), the single greatest threat is siltation, and he placed the major blame for this on surface coal mining. On the basis of Mount's report, a federal process to list *S. depressus* as "threatened" was begun. The present study was initiated in an attempt to provide additional data regarding the current status of the species and to gain some knowledge of the waterways in which it lives.

It should be noted that Seidel et al. (1986) have recently proposed placing the genus *Sternotherus* in the synonomy of *Kinosternon*. For purposes of general familiarity, however, this paper retains the taxon *Sternotherus*.

Methods and Materials

Field work extended from 15 June 1983 until 9 September 1983. Initially (15 June-ca. 15 July), stream conditions were poor for collecting because of high water levels. Rainfall during the first half of the year within the Warrior Basin averaged 22.5-25.0 cm above normal. Thereafter, precipitation decreased dramatically and water levels subsequently declined. Collecting conditions had greatly improved by 15 July and generally remained conducive for trapping and/or wading for the remainder of the study period.

Several methods were utilized in collecting specimens of *S. depressus*. These are in order of decreasing effectiveness: trapping, nocturnal wading with a lantern, diurnal wading, seining, raking and seining through weed beds, and snorkeling.

Traps used were very similar to those previously utilized and described by Mount (1981; after Iverson, 1979) and differed only in that 18 mm mesh rather than 25 mm mesh chicken wire was used. Several designs of traps constructed from corrugated plastic pipe (20 cm and 30 cm diameters) were tested following discussions with several persons who recommended traps with dark interiors. These were later discarded, in favor of the lighter and more easily manipulated wire traps, when results indicated no significant differences in success between the two types.

Traps were set in a wide variety of microhabitats between 1500 hours and 1900 hours and recovered early the following morning. Depending upon logistics, between 30 and 60 traps were set per night (normally 15-20 traps per site). In most instances, traps were spread over a 300-500 m stretch of stream and left undisturbed for 12 to 18 hours. Successful settings ranged in depth from 25 cm to 450 cm and included areas of extremely fast current to pools with virtually no detectable current. Most traps, however, were set at depths ranging from 45 cm to 150 cm in areas with slow to moderate current. We observed that traps placed with one of the long sides flush to the bank, a large boulder, a crevice in the bedrock or a submerged log were, on the average, more effective.

A variety of baits were tested early in the study to determine if one bait type was more effective than others. Chicken parts, chicken livers, various types of canned cat food, canned sardines, canned herring, and native molluscs (snails and mussels ground or sliced and placed in a porous bait pouch) were compared. Canned herring and native molluscs appeared to be the least effective attractants. Because there were no observable differences in trap-capture rates between the other types of baits, canned sardines were used predominantly during the majority of the study because of convenience, cost and relative effectiveness.

Several references were used to assist in the preliminary selection of sampling sites. These included: Alabama County Highway Maps; Geological Survey of Alabama, Atlas Series 12, "Drainage Areas for the Upper Black Warrior River Basin, Alabama (1978)"; U.S.G.S. 7 1/2 minute quadrangle maps; U.S.G.S. 1:250,000 Base Maps (Birmingham and Gadsden); county surface mining maps provided by the Alabama Surface Mining Commission; and the USFWS publication on the status of *S. depressus* by Mount (1981).

Final selection of sampling sites (Fig. 1) was based on two major factors:

Location within the Warrior Basin—The need to provide the broadest possible coverage of known or potential *S. depressus* habitats was considered. Although practical considerations prevented a true random distribution of sites, the overall "scatter" of sampling sites throughout the basin yielded an approximate random distribution.

Specific site selection—Determination of the precise locality for sampling involved consideration of several factors, such as access to a stream, size of the stream, permission of landowner and time limitations. Isolated areas, such as those where access was limited or where access could be gained only by crossing private land, were preferred. Bridge sites were, of necessity, utilized in many instances. Of these, bridge access sites that received minimal disturbance from human recreational activities were normally preferred. Access to several sites could be gained only by boat.

Fifty-seven percent of the streams examined were sampled at more than one site, for one or more of the following reasons:

a) The length of the stream or size of the impoundment necessitated multiple sampling sites in order to compile as accurate an assessment as possible (e.g., Locust Fork, Mulberry Fork, Smith Lake).
b) The presence of particularly good *S. depressus* populations along selected stretches of a stream made it advisable to sample multiple sites. In this way, differences in habitat quality could be compared to population estimates at specific sites within the same stream (e.g., Blackburn Fork of the Little Warrior River, Blackwater Creek).
c) The absence of good *S. depressus* populations within some streams demanded the sampling of more

than one site to minimize the chances of deriving a population estimate which was artificially low (e.g., Clear Creek, Lost Creek, North River, Gurley Creek).

In several instances, a particular locality was investigated more than once. Most were areas which appeared to meet the habitat requirements for flattened musk turtles, but at which trapping results were initially low, primarily due to rain-related stream conditions. At some sites, subsequent efforts revealed the presence of a larger population than would have been suspected after only one attempt (e.g., Turkey Creek, Blackburn Fork, Blackwater Creek). At others, low population density estimates or the apparent absence of the species was supported (e.g., Gurley Creek. Clear Creek, Duck Creek, Locust Fork, Mulberry Fork). Some sites yielded excellent results immediately, and subsequent efforts were made to more accurately estimate population density and population numbers (e.g., Sipsey Fork, Brushy Creek).

A general description of each site was prepared for future reference, and pertinent habitat characteristics noted. These included dominant terrestrial and aquatic vegetation present, characteristics of banks, width of stream, odors, vertebrate and invertebrate associates, water clarity estimates, bottom characteristics, column profile, stream current, dissolved oxygen content (ppm), air and water temperatures, and selected water quality parameters.

A modified Wentworth Scale was employed to determine bottom particle size as follows: boulders = 256 mm or larger; cobble = 64-256 mm; pebble (includes both pebble and granule categories) = 2-64 mm; sand = individual particles visible to the unaided eye up to 2 mm; silt and clay = fine particles individually invisible to the unaided eye. The preceding scale was used to quantify stream bottom characteristics by estimating the percentage of the total for each particle size category present.

Water depth is also an important habitat characteristic for *S. depressus*, as it fluctuates considerably within a stream, both geographically and temporally. Therefore, a column profile was constructed at each sight. The column profile is a proportional representation of various depth categories within the water column. Each of these is expressed as a percentage of the total within the area sampled. The following categories were established: a) riffles = shallow areas with fast current and possessing a roiling surface turbulence; b) <15 cm depth; c) 15-60 cm depth; d) 60-150 cm depth; e) 150-240 cm depth; and f) >240 cm depth.

The exact location, description, and above physical characteristics of each site have been compiled into an Appendix which will be made available to legitimate researchers by the authors upon request. Figure 1 depicts the approximate location of the sites sampled.

Captured flattened musk turtles were taken to the laboratory, assigned an individual identification number by notching the marginal scutes, measured, weighed (to the nearest 0.1 g), photographed and released within 24 hours at the capture site. Previous damage to or erosion of other marginal scutes was noted. Linear measurements (to the nearest 0.1 mm) made with dial calipers were: carapace length, carapace width, plastron length, anterior plastron width, and shell height. Body mass was obtained using a Sartorius top-loading electronic balance (accuracy = ± 0.003 g). Photographs of each captured individual were taken from a position directly above the animal.

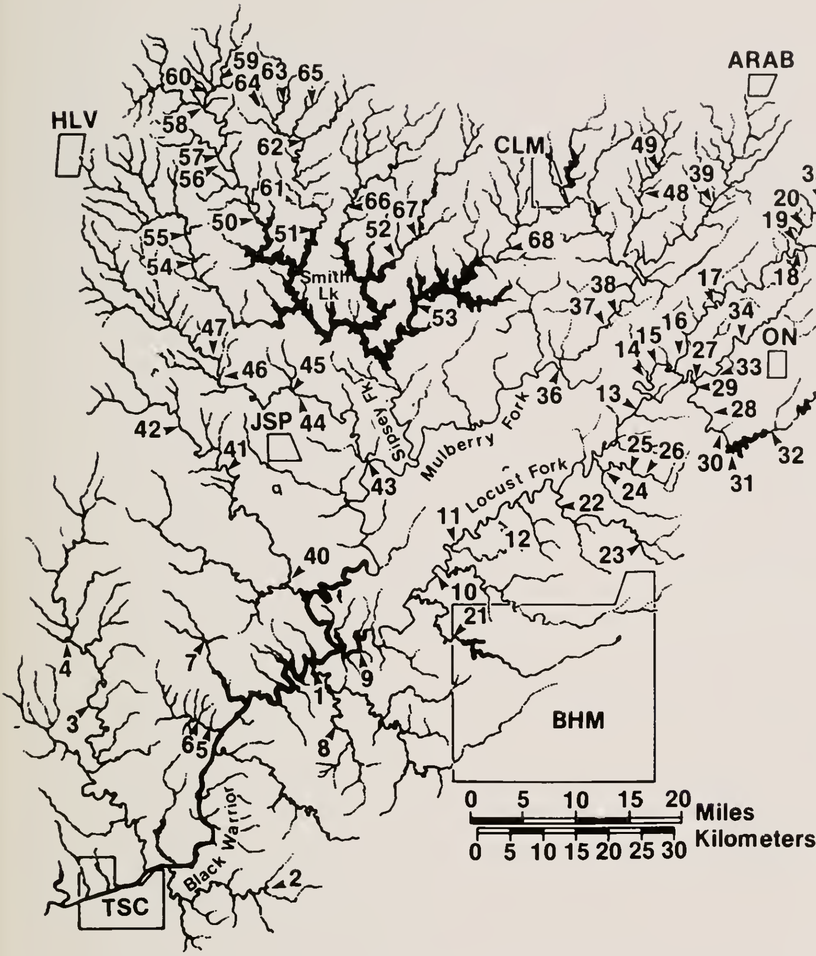

Fig. 1. Map of the Black Warrior River drainage basin showing approximate location of sites examined during 1983. Sites are identified by number. Exact locations and descriptions of sites are available from the authors upon request. Town abbreviations: ALBV = Albertville; ARAB = Arab; BHM = Birmingham; BZ = Boaz; CLM = Cullman; HLV = Haleyville; JSP = Jasper; ON = Oneonta; TSC = Tuscaloosa.

Additional data recorded for each turtle included the presence of old or recent injuries or lesions; sex; the presence of algae, leeches or other epizoics; the presence of oviductal eggs (determined by palpation); whether or not fecal samples were obtained; and the date, site and method of capture.

Interviews with landowners, local residents or others familiar with a particular area or stream often enhanced our understanding of local conditions. On five occasions, we received comments from people who possessed knowledge of important information spanning 20-30 years.

Results and Discussion

A total of 577 *Sternotherus depressus* was collected (Table 1) and approximately 20 others were sighted but escaped. Of those collected, 509 were caught in traps in 20,169.7 trap-hours

TABLE 1. Summary of 1983 collection data by site (see Fig. 1). N = number of *Sternotherus depressus* captured. A size-class distribution by carapace length is given for each site. Trapping efforts (number of nights each site trapped), trap hours and wading hours indicate degree of effort.

Site	N	X̄ Carapace Length (mm) + 1SD (Range)	Size Classes (mm) CL 30-	40-	50-	60-	70-	80-	90-	100-	110-	Trapping Efforts	Trap Hrs.	Wade Hrs.
1	4	94.5 ± 11.6 (80.2-108.0)						1	2	1		1	273	
2	0													21
3	5	83.6 ± 20.2 (64.1-106.4)				2		1		2		1	255	
4	13	94.3 ± 13.9 (65.7-108.3)				2		1	5	5		1	320	
5	11	73.6 ± 19.5 (36.5- 93.6)	1	1	1		3	3	2			1	469	21
6	49	89.6 ± 13.2 (57.2-116.5)			1	4	5	8	24	5	2	2	810	14
7	0											1	442	
8	0											1	171	13
9	14	89.2 ± 11.2 (66.7-105.7)				2	1	3	6	2		1	800	
10	1	70.5					1					1	180	
11	0											1	96	
12	9	90.8 ± 5.9 (82.1- 98.7)						4	5			1	280	
13	0											1	255	
14	6	89.4 ± 16.7 (57.0-105.5)			1				4	1		2	520	5.5
15	4	93.1 ± 3.4 (89.7- 97.7)						1	3			2	425	6
16	0											1	261	
17	0											1	168	
18	7	88.9 ± (84.9- 94.5)						4	3			2	413	
19	4	93.4 ± (79.5- 99.7)					1	2	1			1	324	
20	0											1	160	3
21	0											1	210	2.25
22	29	89.1 ± 8.8 (77.0-110.5)					4	11	11	2	1	3	931	38
23	3	97.0 ± 6.2 (93.1-104.2)							2	1		1	190	
24	0											2	511	
25	0											1	209	
26	0											1	187	
27	9	89.2 ± 20.9 (35.5-105.0)	1					1	5	2		2	425	7
28	2	97.0 ± 4.9 (93.5-100.4)							1	1				10
29	20	84.7 ± 8.1 (70.9- 97.4)					7	7	6			2	656	10
30	14	84.1 ± 12.1 (66.9-102.9)				2	3	4	4	1		2	215	10
31	0											1	320	
32	0											1	360	
33	0											1	283	
34	1	94.2							1			1	275	
35	0													5

36	0										1	200	
37	1	94.9							1		2	332	
38	0										1	160	1.5
39	2	101.2 ± 5.4 (97.5-105.1)							1	1	1	255	2
40	0										1	234	
41	0										1	569	
42	11	83.9 ± 8.5 (64.9- 95.4)				1	2	6	2		1	490	
43	3	62.1 ± 25.2 (36.5- 89.9)	1			1		1			1	112	6
44	20	68.9 ± 18.4 (34.5- 96.3)	3	1		6	5	4	1		4	909	19
45	16	80.8 ± 12.0 (62.1-102.3)				4	2	6	3	1	1	170	
46	0										1	144	
47	0										1	70	
48	0										1	195	4
49	0										1	208	5
50	2	84.8 ± 22.0 (62.2-100.3)				1				1	1	128	
51	13	74.2 ± 13.0 (56.1- 93.6)			1	6	2	1	3		1	160	
52	0										1	144	
53	0										1	255	
54	3	95.0 ± 14.1 (78.8-104.1)					1			2	1	247	
55	2	93.4 ± 5.0 (89.9- 96.9)						1	1		2	671	
56	151	79.2 ± 12.6 (33.6- 98.9)	2	6	3	12	43	65	20		3	441	8
57	86	79.2 ± 14.4 (39.8-106.6)	1	4	6	5	25	24	18	3	1	266	6.75
58	16	91.1 ± 6.7 (80.0-104.0)						9	5	2	1	385	3
59	0										1	251	
60	0										1	182	
61	3	72.7 ± 4.7 (67.4- 76.2)				1	2				1	176	
62	41	82.0 ± 16.8 (37.7-106.9)	1	3		3	8	9	13	4	2	806	23.25
63	0										1	221	
64	0										1	93	
65	0												35
66	1	96.4							1		1	211	
67	1	85.0						1			1	108	
68	0										1	278	

during 1250 trap-nights (mean = 16.1 trap-hours/night) for a rate of 0.41 turtles/trap-night. An additional 68 specimens were hand-captured while wading 265.75 man-hours (0.26 turtles/man-hour). Our rate of capture was not significantly different from that of Mount (1981), who had a yield of 0.4 turtles/trap-night (272 trap-nights) and 0.23 turtles/man-hour wading (44.4 hours). Of the 68 sites sampled, 36 (53%) yielded S. *depressus* (Table 1). Mount collected them at 26 (38%) of 68 sites (approximately half of these sites correspond to those sampled in the present study). Several of the 32 sites that did not yield *S. depressus* in our study had been previously listed as degraded, and the presence of the species considered unlikely by Mount. However, a number of sites where we found turtles were locations where Mount found none (see discussion of waterway status below).

Distribution and Status

Table 2 assesses the status of *S. depressus* at each site. Because no historical population density data are available for the species, the categories in Table 2 are relative estimates of population density. Placement of sites into specific categories was based on 1) collecting results, 2) effort expended, and 3) both qualitative and quantitative habitat evaluation.

The following discussion of distribution and status is presented by drainage from the southwesternmost to the northeasternmost. Refer to Fig. 1 and Table 1 for site locations and collecting results.

A. Black Warrior River (below junction of Locust and Mulberry Forks) and its tributaries.—In Bankhead Lake (Site 1), flattened musk turtles are fairly common around the scattered rocky bluffs, but are low in numbers or absent from the numerous mud flats. The overall assessment is that of a low to moderately dense population. However, access to suitable trapping sites is limited, and trapping at additional sites could reveal a larger population than we estimate. This agrees essentially with Mount's (1981) conclusions that *S. depressus* is locally common in Bankhead Lake.

Hurricane Creek (Site 2), an eastern tributary, was the most degraded waterway sampled. No *S. depressus* were collected, silt deposits were deep, coal fines were abundant, and the pH was 4.2. The only direct evidence of current pollution from surface mining runoff detected during the study was here, where nearby "abandoned mines" (according to ASMC inspectors) were still leaching into the creek. We agree with Mount's (1981) conclusion that essentially no *S. depressus* survive in this stream.

Healthy populations of moderate density were found at two sites on the

TABLE 2. Status of the flattened musk turtle at sites examined during 1983. Refer to Fig. 1 for approximate site locations. Exact locations and descriptions of sites are available from the authors upon request. Status determinations are relative estimates of density based on 1) collecting results, 2) effort expended, and 3) both qualitative and quantitative habitat assessment.

Population Assessment	Sites
Absent	2, 21, 60, 63, 64
Absent to Low	7, 8, 11, 13, 16, 17, 20, 25, 26, 31, 32, 33, 35, 36, 38, 40, 41, 46, 47, 48, 49, 52, 53, 65, 68
Low	10, 15, 19, 23, 24, 34, 37, 39, 55, 59, 66, 67
Low to Moderate	1, 9, 14, 18, 43, 50, 54, 61
Moderate	3, 4, 12, 27, 28
Moderate to High	22, 29, 30, 42, 44, 45, 51, 58
High	5, 6, 56, 57, 62

North River (Sites 3, 4). However, runoff from agricultural areas and siltation are evident.

Blue Creek is a stream in which Mount (1981) found no turtles, but he concluded that conditions there were acceptable, and thought *S. depressus* probably well-represented. The populations at Sites 5 and 6 (approximately 1.6 km apart) are healthy, reproducing, and of high density. However, the stream does not fit the criteria given by Mount (1981) for optimal habitat. The stream bed is extremely sandy, with some boulders and rock crevices present. The original substrate is largely obscured by sand, up to 60 cm deep in places. Blue Creek is of particular interest since it is apparently recovering from severe past pollution as a result of nearby surface mining. Local residents told us that the turtle and fish faunas were "completely wiped out" over 20 years ago when the contents of a sedimentation basin flooded into it. Mining operations ceased about 10 years ago. The presence of a high density population today apparently indicates that the species can naturally repopulate areas from which it has been eradicated. The turtles apparently immigrated either from areas above those affected by mining and/or the Black Warrior River, of which this stream is a direct tributary. The musk turtles taken from Blue Creek seemed intermediate in head pattern and shell depth between *S. depressus* and *S. minor peltifer*, but whether this represents hybridization or merely intergradation is not known.

Big Yellow Creek (Site 7) is a small, intermittent, silty stream that may infrequently support *S. depressus* near its mouth. Agriculture is prevalent in the area, and there are several old surface mines 5-6 km upstream. *S. odoratus* is common in Big Yellow Creek and may outcompete *S. depressus*. Mount (1981) considered *S. depressus* to be scarce or absent in this waterway, and we concur.

Mud Creek (Site 8), a heavily-sedimented tributary of Valley Creek, has historically been influenced by agriculture, surface mining and coal-related industries. High water levels at the time of sampling may have contributed to our collecting no flattened musk turtles there, but probably at best only a low density population exists at this site.

B. Locust Fork and its tributaries.—Mount (1981) considered the ecological condition of the Locust Fork to be poor, and we concur. Overall, it is degraded; the upper portions are heavily impacted by agriculture and to a lesser degree by surface mining. In our opinion, agriculture has probably had the greater impact in the upper Locust Fork. Extensive algal growths cover the rock substrate in many areas, possibly indicating excess nutrient influx. Sediments in many places are also typical of those associated with runoff from cultivated areas. Such sediments typically consist of fine particulates possessing a flocculent appearance. The possibility exists that pesticide/herbicide influence in these (and other) areas has had a debilitating effect. Coal fines and other evidence of mining-related activities are less obvious. The lower portions, however, have been more severely affected by surface mining, and industrial and municipal pollution. In some areas, old surface mines abut the river's edge. Habitats in the extreme lower portion have also been modified by reservoir backup. All 12 sites sampled during the 1983 study resulted in below average collections, and all of these sites showed some evidence of degradation. The data presently available suggest that *S. depressus* populations in the Locust Fork have declined. There are still low to moderate density, reproducing populations at Sites 9, 14 and 19. Populations at other sites, however, such as 10, 11, 13, 16, 17 and 20, are very low in density or have been eradicated. Those at 12, 15 and 18 are low density and may not be successfully reproducing. Previous scientific collecting on the Locust Fork indicated moderate to high density populations at some localities (Mount, 1981; Cox, personal experience; James V. Peavy, personal communication). In addition to habitat degradation, collection for the pet trade appears to have been a major factor in the decline at certain sites. The populations at easily accessible sites, such as 16 and 18, have been especially affected by collectors. Mount (1981) provided comments on Site 18. At Site 16, Cox collected 15 *S. depressus* in 10 man-hours wading during 1977, and Peavy reports having seen numerous individuals at this site during the period 1966-1976. We caught no *S. depressus* at this location during our survey, despite ideal collecting conditions. Since gastropods and *Corbicula* (important food items in the diet of adult *S. depressus*) were usually abundant at most sites on the Locust Fork during our study and the general physical characteristics (current, rock substrate, refugia) appear acceptable, the lack of success in obtaining flattened musk turtles at these and other Locust Fork localities was startling.

Village Creek (Site 21) has been highly polluted by both industrial and municipal effluents in the past, and appears degraded and presently eutrophic. No snails or clams were observed, and it is unlikely that *S. depressus* still exists in the creek. However, our one collecting attempt was during a period of high water. The fish fauna seems abundant and varied, and perhaps the stream is recovering.

Turkey Creek (Sites 22, 23) has been heavily influenced by surface mining and, to a lesser degree, by agriculture and other human activities (e.g., road-building, construction, urbanization, etc.). Mount (1981) considered the presence of *S. depressus* unlikely. Turkey Creek at Site 23 is small and considerably degraded, with a heavy silt load and obvious coal fines; a large inactive surface mine is located upstream. Only a low density *S. depressus* population is present. Site 22, downstream from 23, is also degraded with silt and coal fines, but in all other respects appears to be favorable habitat, having large boulders, riffles and weed beds. There are extensive sand deposits on the bottom; snails are abundant and *Corbicula* are present. The *S. depressus* population at this site is one of moderate density. If this population is left undisturbed, it has the potential for naturally restocking those sections of the stream that retain suitable habitat characteristics.

We trapped but did not wade three sites on Gurley Creek (Sites 24, 25, 26) and caught no *S. depressus*. Historically, it has been affected by surface mining and municipal pollution. Some segments of the stream are still degraded, while others appear able to support these turtles. Mount (1981) arrived at essentially the same conclusions. Possibly a low density population of *S. depressus* is present, as potential food items (*Corbicula*, snails, and aquatic insect larvae) are moderately abundant and the physical habitat appears acceptable.

The Blackburn Fork (Sites 27, 28, 29, 30) contains favorable habitat for *S. depressus*, and the present overall density is moderate to high. Populations are more dense in the upper reaches. However, the population appears to have declined in recent years, especially at Site 28 (Cox and Marion, past experience), and this decline is probably attributable to commercial collecting. Site 28 has been extensively collected during the past ten years by amateurs and commercial collectors and is well known throughout the southeast by those interested in flattened musk turtles. Discussions with several people who are familiar with the pet trade (and comparing figures provided by them) yields a conservative estimate of 300-400 turtles removed from this stretch during the last ten years. If recent state legislation prohibiting commercial collecting is enforced, however, the Blackburn Fork overall should continue to support a large breeding population of *S. depressus*; the water quality is good and food is abundant.

No flattened musk turtles were collected at two sites (31, 32) on Inland Lake, despite setting 40 traps for two consecutive days. It is a large, deep, cold, rocky reservoir, with water depths dropping off sharply near the shoreline. No molluscs or gastropods and few other potential *S. depressus* food sources were observed, even while scuba diving. The species may no longer be present in the lake.

Calvert Prong (Sites 33, 34) has been heavily influenced by agricultural runoff and possibly surface mining (Mount, 1981), and appears degraded. A low density *S. depressus* population is present. The possibility of additional natural restocking exists, as there is a moderate to high density population in the Blackburn Fork upstream from the confluence with Calvert Prong. A fisherman, when shown a flattened musk turtle, said he was familiar with the animal, and that he had seen them at Site 33. We caught none there in traps, but the habitat appeared suitable.

Slab Creek (Site 35) is small, with a silt-sand bottom. Sedimentation is heavy, and fine sediments typical of nearby agricultural utilization uniformly cover all rock substrate to a depth of 1.5 cm. *Corbicula* are abundant, but no snails or aquatic insect larvae were observed. Although we collected no *S. depressus* while wading one hour (1200-1300), a low density population may occur.

C. Mulberry Fork and tributaries.—The Mulberry Fork (Sites 36, 37, 38, 39) has been considerably degraded by agricultural siltation (and possibly pesticides/herbicides) and perhaps by effluents from several municipalities. Surface mining has had little effect except in the lower reaches, where commercial collecting has also occurred. Mount (1981) thought this stream supported a low density population of *S. depressus*, and this is also our assessment. The population is probably declining; according to one source, commercial collectors found it more difficult to obtain specimens in 1982-83 than in previous years.

Lost Creek (Sites 40, 41, 42) has some areas of suitable habitat remaining in the upper stretches. A moderate density, reproducing population of *S. depressus* exists near Pocahontas (Mount, 1981), and we found a moderate to high density reproducing population near Cedrum (Site 42). We trapped 11 specimens there after heavy overnight rains made collecting conditions suboptimal. This site contains numerous shelves of eroded stratified rock; snails, *Corbicula*, and aquatic insects are abundant. The lower and middle stretches, however, have been strongly influenced by past and present surface mining, agriculture and impoundment (Sites 40, 41), and collecting efforts were unsuccessful. At best, a low density population may still exist in the lower reaches of the stream.

Mount (1981 considered the *S. depressus* population in Blackwater Creek (Sites 43, 44, 45, 46, 47) to be the most extensive and important in this portion of the species' range. This is especially true of the midreaches of the stream. We also found these areas to be favorable habitat and still supporting a moderate to high density population. However, many sites are readily accessible to human disturbance. The upper reaches are degraded with silt and some coal fines; agriculture and mining have both affected these localities. The confluence of Blackwater Creek with the Black Warrior River (Site 43) is the type locality of *S. depressus* (Tinkle and Webb, 1955), and a low to moderate density, reproducing population still occurs there (possibly reinforced by turtles entering from the Black Warrior River). This site has apparently not changed appreciably since it was described as the type locality (J. Whitfield Gibbons, personal communication following on-site inspection).

Duck Creek (Sites 48, 49) is small, but *Corbicula* are abundant and the physical characteristics are well within the limits of favorable habitat observed elsewhere. Possibly a low density population of *S. depressus* occurs there, although repeated efforts (Mount, 1981, and present study) have failed to produce specimens. The heavy concentration of agriculture along this stream (and, indeed, all of those within Cullman County) has probably adversely affected the species. Fine sedimentation is moderate to heavy in some locations and extensive algal growths indicate probable organic enrichment. Although there are no historical records indicating dense populations in this and other streams within Cullman County, the habitats appear suitable, and adequate routes for dispersal from populated drainages have historically been present. These facts strongly suggest that *S. depressus* was present in these streams in the past.

D. Smith Lake.—We sampled four sites (50, 51, 52, 53) on this large reservoir (8,550 ha). Low to moderate density S. *depressus* populations occur at the mouths of the Sipsey Fork and Brushy Creek in Winston County (Sites 50, 51), but only low density populations are present at the confluences of Crooked Creek and Ryan Creek with Smith Lake in Cullman County (Sites 52, 53). Many areas of suitable physical habitat are found in the lake, with rock shelves and boulders abundant, and probably low to moderate density populations of turtles occur at these scattered sites. However, the steep bluffs and scarcity of shallow water habitat in the lower reaches may hinder or prevent turtles from inhabiting or colonizing the main portions of the lake. Further, populations of potential food items may be low in these regions. Mount (1981) sampled four sites in Winston County and believed a healthy, but low density, population inhabited the lake. A massive effort would be required to fully assess the population density of flattened musk turtles along the extensive shoreline of Smith Lake. The average population density for Smith Lake in its entirety is probably low. It does, however, possess the potential for supporting a large total number of *S. depressus*, especially if isolated populations are considered in aggregate.

E. Streams tributary to Smith Lake and their tributaries (major tributaries arranged from west to east, and their tributaries from north to south).—Clear Creek lies west of the Bankhead National Forest and traverses an area of intensive agriculture. We sampled two sites. The lower site (54) has sufficient rock crevices for cover and a moderate supply of snails for food. Sand deposits are extensive and and the site apparently supports a low density, and probably reproducing, population of *S. depressus*. The upper site (55) is a less suitable habitat, with few rock crevices, a very sandy bottom, and little molluscan food, but an occasional flattened musk turtle can still be found. Generally, the lower reaches of the creek seem to be better habitat than those areas upstream. Agriculture appears to be the major influence along much of the stream, as there are areas of occasional brown surface "foam" and extensive algal growths on the submerged rocks, both indicative of organic enrichment. Mount (1981) felt that Clear Creek had acceptable physical habitat and that *S. depressus* was moderately common. He suggested that low food availability was the most important limiting factor at Camp McDowell.

The Sipsey Fork was sampled at four sites above Smith Lake. Site 50 (at the confluence with Smith Lake) supports a low to moderate density population of *S. depressus*. Upstream, Site 58 on the West Sipsey Fork at Cranal Road (Bankhead National Forest) was sampled by us and also by Mount (1981). The site has some deep pools and rock crevices, but also has several sandy stretches. We found both snails and *Corbicula* present, and our data indicate that a moderate to high density, reproducing population occurs there. However, this is a recreation area, and human disturbance may adversely influence the turtle population. Mount (1981) considered the habitat relatively good and *S. depressus* "moderately common", but that population levels are probably limited by low food availability. Sites 56 and 57 are separated from each other by about 1.6 km and are downstream from Site 58. Although boulders and some rock crevices are present, the bottom is extremely sandy. Snails, *Corbicula* and insects are common to abundant. The *S. depressus* population at Sites 56 and 57 is one of extremely high density and is healthy and reproducing. In fact, this portion of the Sipsey Fork supports the densest population of *S. depressus* recorded to date (Table 1).

Borden Creek, a shallow tributary of the Sipsey Fork, was trapped at one site (59). No turtles were collected, but some areas appeared to be suitable habitat. *Corbicula* were common and some snails were present. The stream widens and deepens below the bridge access, and the presence of *S. depressus* between that point and the confluence with the Sipsey Fork, approximately 1.6 km downstream, is considered probable. However, due to the short length of this stream segment and general character of the habitat, only a low density population should be expected. Braziel Creek (Site 60), a small tributary of Borden Creek, contains marginal habitat, and few if any flattened musk turtles occur there.

Brushy Creek was sampled at four sites (51, 61, 62 and 63). We found a low to moderate density, reproducing population at U.S. 278 (Site 61), but the habitat was somewhat degraded by logging operations. A high density, reproducing population of *S. depressus* is present at Site 62, which is easily accessible by a Forest Service road. *Corbicula* and snails are common, and the stream drainage is densely forested. At Brushy Creek Lake, a shallow, swampy impoundment on the upper reaches of the stream (Site 63), we caught no *S. depressus* and the physical habitat was unacceptable. There is, however, a sizeable population of *S. odoratus* in the lake. The confluence of Brushy Creek and Smith Lake at County Road 63 (Site 51) supports a moderately dense population. A wide size-class range (46.1 mm to 93.6 mm CL) was captured, and the presence of smaller animals indicates a reproducing population. Brushy Creek arm below this site probably continues to support a moderately dense population, at least in areas of suitable habitat.

Limited trapping in Beech Creek (Site 64) produced no *S. depressus*, and our data and observations of habitat characteristics suggest they are absent. It is a small tributary of Brushy Creek, with poor habitat and low food availability. Another Brushy Creek tributary, Rush Creek (Site 65), may have at best a low density population of *S. depressus* in the lower reaches. It is shallow and the habitat questionable; few large rocks or hiding places are present. This site was waded once, and collecting conditions were good. Lower water levels later in the season alter habitat conditions, and the stream probably does not retain sufficient water depth for safe permanent occupancy by musk turtles.

Rock Creek (Site 66) supports a low density population of *S. depressus*. There are heavy sand deposits and evidence of organic enrichment, probably due to agriculture. Trapping was minimally successful. *Corbicula* are fairly abundant, and several defecated piles of *Corbicula* fragments were also observed. Mount (1981) examined Rock Creek at Smith Lake where it is a narrow, deep channel, and felt that the presence of *S. depressus* was unlikely at that locality.

Crooked Creek in Cullman County (Sites 52, 67) supports only a low density population of *S. depressus*. The stream is marginal habitat at best; it is small and shallow, with little rock substrate and low food availability.

Ryan Creek (Site 68) is agriculturally silt-degraded; *Corbicula* are present, but no snails. No *S. depressus* were detected and, if the species is present, the creek supports only a low density population.

Habitat

Mount (1981:23), based on his collections, proposed the optimal habitat for *S. depressus* to be "a segment of a free-flowing large creek or small river having the following characteristics: (1) drainage area between 50 and 500 mi^2, (2) depth averaging 2 ft., with vegetated shallows alternating with pools at least 3 1/2-4 ft. deep, (3) pools with detectable current, (4) an abundance of submerged rocks with crevices, overlapping flat rocks, or accumulations of boulders, (5) abundant molluscan fauna, (6) low silt load and minimal silt deposits, (7) relatively low nutrient content and bacterial count, (8) moderate temperatures (max. 85°F), and (9) minimal pollution by synthetic chemicals and toxic inorganic materials." We generally agree with these habitat requirements and can further substantiate the importance of certain of these characteristics. Over the stream section surveyed at each site, we were able to quantify average depth, per cent bottom cover, and amount of silt coverage on the stream bottom. We also qualitatively estimated stream size, current, and molluscan population levels on a scale of 1 (smallest or lowest) to 3 (largest or highest). In order to relate turtle population size to these stream characteristics, negative scores were given to a site for any of the following (based on comparative site differences): if an average depth of two feet did not occur in at least 50% of the area surveyed; if boulders, rock substrate and cobble did not exceed or equal 40% of the stream bottom area; if fine silt covered more than 15% of the bottom; and if any of the qualitatively-judged characters scored a "1". A Spearman's rank correlation test (SAS Institute) demonstrated a significant negative relationship between population size at a site (using the seven categories in Table 2) and the total number of negative stream characteristics, using the six we were able to measure or estimate ($rs = -0.929$; $P = 0.003$). Indeed, of the 18 sites ranked with moderate or greater *S. depressus* levels, only one had more than one negative character, and the five high density population sites had no negative characteristics.

However, many of the sites we examined, and especially those in which we found the highest density populations, varied somewhat from these criteria. Particularly notable is that we found sand to be a much more ubiquitous characteristic of *S. depressus* habitat than has been recognized in the past. Sandy habitats, when coupled with (a) adequate exposed bedrock, boulder, or cobble substrate, and (b) a sufficient food supply (snails, *Corbicula*, and aquatic insects), often support dense populations of flattened musk turtles. In fact, the five sites judged to support the highest density populations (Sites 5, 6, 56, 57 and 62) all had extensive sand deposits (≥35% coverage of stream bottom), sometimes as deep as 60 cm and obscuring as much as 75% of the rock substrate. We have seen *S. depressus* burrow into the sand and have collected others that had already buried themselves. The specific nature of sandy sediments also plays a role. For example, the species seems to avoid areas in which the sand is firm or hard-packed, unless there are other suitable refugia nearby (i.e., boulders, bedrock crevices, holes in banks, etc.). Apparently, such areas are suitable for foraging, as we have captured specimens in traps set there. We have not, however, observed *S. depressus* burrowing into hard-packed sand. For the most part, turtles seem to burrow in loose sand or in a combination of sand-silt and sandy-clay substrate.

Whereas sandy habitats may support good populations of *S. depressus*, finer sediments (silt and clay), on the other hand, do appear to be a decisive factor in determining habitat quality for the animal, in that areas with heavy deposits of fine silt and clay sediments do not support large populations. A Spearman's rank correlation test comparing the number of sites at each population assessment category with the occurrence of a high silt load (>15% coverage of stream bottom) revealed a significant negative relationship between population size and stream silt load ($rs = -0.929$; $P = 0.003$).

Adequate bottom cover at a site was also significantly correlated to *S. depressus* population levels. Using a criterion of ≥40% coverage of the stream bottom by bedrock, boulders, and cobble as adequate bottom cover, we found a positive relationship between population size and bottom cover ($rs = 0.857$; $P = 0.014$).

Finally, though food was not quantitatively measured during our study, each site was qualitatively judged as to whether bivalves and snails, primary *S. depressus* food items, were in low, medium, or high numbers. Food abundance appeared strongly linked to turtle abundance, as only 2 of the 18 sites ranked as having moderate-sized or greater *S. depressus* populations were judged to be deficient in food. By contrast, at many sites where *S. depressus* populations were ranked as low or absent, food levels were also low.

Daily Activity Patterns

Estridge (1970) and Mount (1981) both commented that juveniles have a greater daily activity span than do adults, which are predominantly nocturnal. We agree essentially with this, and can provide additional observations made while wading. Fewer active adults than juveniles (7 versus 9) were hand-collected during the daylight (non-twilight hours), and the juveniles collected then were usually of the smaller size classes (<50 mm CL). Juveniles became more active at twilight, with most captures occurring during this period, and as darkness increased, so did activity involving all size classes. Though precise records were not kept, there seemed to be a correlation between the time of day and the size of active turtles. In early evening we observed more juveniles foraging, but as night progressed more young.adults emerged, followed by the very large adults after 2200 hours.

Predation

We found only two dead predated *S. depressus*. Both had apparently been killed by raccoons, whose tracks were found nearby. Several other live individuals were missing limbs or tails. However, flattened musk turtles are small, and many (especially juveniles) can be swallowed whole by large predators, while even adults could easily be carried off to be eaten elsewhere. Predation on juveniles is probably high, and nesting females are more vulnerable while on land.

Health

We found no evidence of diseased *S. depressus*, although they were heavily parasitized by the leech *Placobdella parasitica*, which carries the protozoan agents (*Haemogregarina* and *Haemoproteus*) of turtle malaria (Ernst and Ernst, 1979). Estridge (1970) found *Haemogregarina* in three of seven *S. depressus* he examined. Mount (1981) reported that two of five specimens captured while basking at a Jefferson County site had abscesses presumably caused by bacteria. He thought that such basking behavior was abnormal and possibly related to their diseased condition. Basking probably occurs much more frequently in this species than has been previously reported. Healthy individuals we have kept in the laboratory readily climb out of the water when provided with basking platforms and heat lamps. We have also seen basking in the wild, and J.V. Peavy (pers. comm.) reports observing extensive basking by *S. depressus* along some streams while canoeing.

Conclusions

The present study demonstrates that *S. depressus* is more prevalent within its range than previously thought. Eighteen (26%) of the 68 sites sampled had moderate to high density populations, and an additional 8 sites (12%) had population densities which we regarded as between low and moderate (Table 2). Unfortunately, some sites could be visited only once, due to the constraints of time and logistics. As we have mentioned, initial collecting efforts at some localities failed to produce specimens, but subsequent attempts revealed the presence of good populations (e.g., Turkey Creek, Blackburn Fork, Blackwater Creek). The results of a single attempt, even with adequate trap numbers, can therefore yield an underestimation of population density.

Mount (1981) inferred from his and other existing data that discreet populations of *S. depressus* may have substantially fewer juveniles today than prior to 1970. Table 3 compares the size-class distributions obtained by: (a) pooling results for all pre-1970 studies, (b) Mount (1981), and (c) the present study. The pre-1970 data are based on several collections made by different collectors (during different years and at different periods within the collecting season) using various collecting techniques. Literature records suggest that wading and collecting by hand were the primary collecting methods employed in these earlier studies. In the present study and that undertaken by Mount (1981), the major emphasis was placed on trapping. In our experience, smaller juveniles are only occasionally collected by trapping, due probably to the mesh size of the traps (1.8-2.5 cm), through which small individuals can move with ease. Differences in dietary preferences in large vs. small turtles may also influence trapping results. The percentage of smaller individuals (<60 mm Carapace Length) is much greater in samples obtained by wading and collecting by hand (under suitable habitat conditions). Therefore, the otherwise most efficient collecting technique (trapping) appears to introduce a selective bias favoring the capture of larger individuals (≥60 mm CL). Mount (1981) waded a total of 44.4 hours and collected 6 juvenile *S. depressus* <60 mm CL. In the present study, 34 juveniles were collected during almost 250 hours wading. Catch-per-unit-effort calculations are virtually identical in both studies, with each juvenile requiring about 7.5 hours effort. Table 1 indicates that juveniles <60 mm CL were captured at 9 (56%) of the 16 waded localities at which we caught turtles, while only two were caught in traps during the entire study. Published studies on turtles indicate that in some species juveniles apparently comprise a low percentage of the population (see Harless and Morlock, 1979, for summary), although to what extent sampling bias (similar to that seen in *S. depressus*) has played a role is unknown. In addition, in almost all turtle populations juveniles are more difficult to detect. The size-class distributions obtained by Mount (1981) and in the present study (Table 3) are remarkably similar to those obtained in a northern Florida spring for *S. minor* (Cox, 1978), in which snorkeling and trapping were the major collecting techniques employed under almost ideal conditions. Also, the percentage of juveniles collected by Mount (1981) and in this study are not particularly low when compared to findings in

TABLE 3. Comparison of size-class distributions (mm carapace length) of flattened musk turtles collected prior to 1970, by Mount (1981), and during the present study (1983). Specimens considered intermediate between *Sternotherus depressus* and *S. minor peltifer* are not included. Numbers collected are indicated below each size class. The percentage of the total for each size class is given in parentheses.

	Size Class (mm CL)								
	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100+	Total
Combined pre-1970 Samples (adapted from Mount, 1981, and Estridge, 1970)	18 (26%)	6 (9%)	7 (10%)	7 (10%)	8 (11%)	9 (13%)	12 (17%)	3 (4%)	70
Mount, 1981	1 (1%)	1 (1%)	4 (4%)	8 (8%)	13 (13%)	29 (29%)	35 (35%)	10 (10%)	101
Present Study, 1983	9 (2%)	14 (3%)	11 (2%)	44 (9%)	107 (22%)	164 (32%)	123 (25%)	26 (5%)	498

populations of various other turtle species (Legler, 1960; Ernst, 1971, 1976; Brown, 1974; and Vogt, 1980). Although the size-class distribution in Table 3 for pre-1970 studies might reflect real population structure, it is most remarkable for its bimodal distribution, rather than for its similarity to results from other studies. This suggests that pre-1970 investigators (with emphasis on hand-collecting) inadvertently biased their samples in favor of smaller individuals. Thus, we conclude that the evidence is not compelling enough to warrant an *a priori* acceptance of Mount's (1981) hypothesis regarding a decline in the percentage of juvenile *S. depressus.*

One of the problems that has faced *S. depressus* has been commercial collection. Although we do not know just how extensive this has been, or to what extent this may have reduced specific population levels, serious overcollecting without regard for population dynamics has been reported to us by several sources who have contacts within the pet trade. Selected areas along the Mulberry, Locust and Blackburn Forks have reportedly received much attention from commercial collectors. State legislation (1984) now prohibits the taking of *S. depressus* except for valid scientific purposes and requires a special permit. Hopefully, this will serve to reduce collecting pressure on the species. However, recent unconfirmed reports during 1985 indicated that some commercial collecting may still be occurring.

We have also found the question of sedimentation to be more complex than previously realized. First, although sediments from surface mining were present at many sites, the major source of sedimentation appears to be agriculture throughout most of the Black Warrior River drainage. We found agricultural sediments in almost all of the waterways examined. They were particularly noticeable in Cullman County, and elsewhere, both the Mulberry Fork and Locust Fork have been adversely impacted. Sand sediments do not appear to be particularly harmful, and many of our highest density populations were associated with extensive (moderate to heavy) sand deposits. There is, however, an inverse correlation between the amount of silt and clay sedimentation and the population density of *S. depressus.* No cause and effect relationship, however, has yet been established.

Early in this study, observations at various localities suggested that certain trends regarding land use practices correlated with habitat degradation. Although neither formally stated nor rigorously tested, our subsequent experiences and qualitative observations have strengthened this perception. We conclude that the two greatest influences affecting habitat quality, and therefore affecting populations of flattened musk turtles, are surface mining and agriculture. There is no doubt that surface mining can have a drastic effect, especially upon local populations that are near active or abandoned mines that are still leaching into the stream. The devastating effects of a massive influx of mining residues upon the Blue Creek population (Sites 5, 6) have been well documented. However, this population has recovered remarkably well in only a 10-20 year period. Long-term problems can also occur, though, especially when abandoned mines are not reclaimed (i.e., Hurricane Creek, Site 2). The effects of mining, therefore, are often immediate and obvious, but in some cases the damage is reversible. The streams of Cullman County, and the upper Mulberry and Locust Forks, however, present an entirely different picture. In these areas of intensive agriculture, the effects of organic enrichment, siltation, and the possible presence of pesticide/herbicide residues suggest a slow, long-term and insidious degradation of habitat. Just how serious this is, or will be in the future, is not known. No study to date has addressed the potential problems presented by agricultural influence on these waterways and upon their attendant aquatic biota.

Mount (1981) concluded that *S. depressus* meets the criteria for inclusion on the federal threatened species list, and he placed the major blame for the species' decline on siltation from surface mining. There is, unfortunately, little historical data from which to make population comparisons. The present study reveals *S. depressus* to be somewhat more numerous than previously thought, with high density populations at Sites 5 and 6 (intergradient?), 56, 57 and 62, and moderate to high density populations at Sites 22, 29, 30, 42, 44, 45, 51 and 58. We conclude that *S. depressus* is a case for special concern, but that its candidacy for inclusion on the federal threatened list is inadvisable at the present time. We do feel, however, that continued monitoring of its status is justified. In addition, the present lack of knowledge regarding populations in the major impoundments (Bankhead Lake, Smith Lake, Lake Tuscaloosa) precludes a complete understanding of the species' status. Finally, four streams are crucial to our assessment regarding the present status of *S. depressus*. These are Blackwater Creek, Blackburn Fork, Sipsey Fork and Brushy Creek. Should any one of these populations decline appreciably or should illegal commercial exploitation continue in these streams, federal protection may be warranted.

Acknowledgments

We would like to thank several persons and organizations for their aid during this study. Charles Dixon, Britt Morris, Bruce Thompson, and Steve Thompson assisted us in the field and laboratory. Without these student assistants we could not possibly have gained such results as we achieved. Dick Darby provided use of a boat during our lake studies. Dr. J. Whitfield Gibbons, Savannah River Ecological Laboratory, accompanied us in the field on one occasion and contributed many useful suggestions on collection methods and habitat assessment. James V. Peavy provided historical collecting data and personal observations on selected populations of *S. depressus*. Perry Hubbard acted as liaison between the Field Directors and Sponsors, and we are grateful for his assistance. Drs. R. Christian Jones and Donald P. Kelso, George Mason University, discussed with us the water quality parameters to be measured, and Drs. W. Mike Howell and Robert Stiles, Samford University, provided information on the aquatic ecology of the Warrior Basin, as well as encouragement. We also thank various property owners for allowing us to collect on their lands and for information pertaining to local history of the waterways involved. Samford University provided laboratory space and equipment during the project, and George Mason University liberal leave for Ernst. Finally, we acknowledge the Alabama Coal Association for project funding, logistical assistance, and cooperation in our conducting the research free of interference.

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