

THE USE OF HABITAT CLASSIFICATION AND MAPPING
OF THE THREATENED FLATTENED MUSK TURTLE
IN THE SHORELINE MANAGEMENT OF
SMITH LAKE, ALABAMA

by

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ABSTRACT

The purpose of this thesis was to develop a habitat classification system indicating suitability of shoreline for the federally threatened flattened musk turtle (*Sternotherus depressus*). The shoreline of Smith Lake was visually assessed by a biologist familiar with *S. depressus*. Segments of shoreline were designated “Good”, “Moderate” or “Poor” relative to substrate type. *Sternotherus depressus* prefers large rock with an abundance of crevices which it uses for protection. To ground truth the habitat classifications, 155 sites along the shoreline were trapped for *S. depressus* for three trapping seasons (spring and fall 2011, spring 2012). A total of 58 *S. depressus* individuals were trapped at 25 separate sites. Of these 25 sites, 14 were in “Good” habitat, nine were in “Moderate” habitat, and two were located in “Poor” habitat. A chi-square test for independence indicated that there is an association between the presence or absence of *S. depressus* and habitat type ($\chi^2 = 8.463$, $N = 155$, $p = 0.015$) at the trap site. The habitat classification system will be used by Alabama Power Company in its shoreline development program to help reduce adverse effects upon *S. depressus* or its habitat on Smith Lake.

LIST OF ABBREVIATIONS AND SYMBOLS

ADEM	Alabama Department of Environmental Management
APC	Alabama Power Company
C	Celsius
CL	carapace length
cm	centimeter
EIS	environmental impact statement
ESA	Endangered Species Act of 1973
F	Fahrenheit
FERC	Federal Energy Regulatory Commission
HCP	habitat conservation plan
km	kilometers
LTR	Little Tennessee River
mg/L	milligrams per liter
m	meter
mm	millimeter
NEPA	National Environmental Policy Act of 1969
SMP	shoreline management plan
T&E	threatened and endangered
TVA	Tennessee Valley Authority
USACE	U.S. Army Corps of Engineers

USFWS U.S. Fish and Wildlife Service

χ^2 chi-squared:

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CHAPTER 1

INTRODUCTION

Since the Endangered Species Act (ESA) was passed in 1973, the status of wildlife has played a more prominent role in determining the development and management methods of U.S. land. Specifically in shoreline management, activities such as building new structures, drawdown of reservoirs, forestry practices, water withdrawals, and other practices must account for the effects they produce upon threatened and endangered (T&E) species populations. Entities that regulate these waterbodies often form shoreline management plans (SMPs) that address and explore many issues, including T&E species protection. The flattened musk turtle (*Sternotherus depressus*) was listed as a federally threatened species in 1987, after a series of scientific studies examined the population status and distribution of the turtle species (Mount 1981; Dodd *et al.* 1986; Ernst *et al.* 1983). This thesis examines the development and accuracy of a habitat classification system designed to limit adverse effects on *S. depressus* in shoreline development activities.

Sternotherus depressus is a small freshwater turtle endemic to the Black Warrior River Basin above the Fall Line (Figure 1.1). It gets its name from its flat carapace, which sets it apart from other species of musk turtles, which have a more dome-shaped carapace. A mature *S. depressus* rarely exceeds 11 cm carapace length (CL). The carapace is yellowish brown to dark brown in color and can have dark spots or streaks, while the plastron is pink to yellowish brown (Ernst *et al.* 1994). *Sternotherus depressus* was first identified as a distinct species by

Tinkle and Webb in 1955. Their diet consists primarily of gastropods (snails) and pelecypods (clams and mussels), with occasional insects, crayfish and plant seeds (Marion *et al.* 1991; Tinkle and Webb 1955). The introduced Asian clam *Corbicula* is thought to be an important food source for *S. depressus* (Mount 1981). *Sternotherus depressus* has different food requirements at different life stages, as juveniles tend to prefer softer-bodied benthic macroinvertebrates, while adults subsist on gastropods and bivalves (USFWS 2009). The predators of juveniles include wading birds, some predatory fish species (*Ameiurus* sp., *Ictalurus* sp., *Lepisosteus* sp., *Micropterus* sp.), and large common snapping turtles (*Chelydra serpentina serpentina*) (Ernst *et al.* 1994). Raccoons (*Procyon lotor*) are thought to feed on both age classes (Ernst *et al.* 1989; Ernst *et al.* 1994).



Figure 1.1 Flattened musk turtle (*Sternotherus depressus*). (Source: Mark Bailey, Conservation Southeast)

Little is known about the nesting behavior of *S. depressus*. Close (1982) estimated that males typically reach sexual maturity at 4–6 years of age, while females typically take 6–8 years to mature. However, Melancon *et al.* (2011) studied the growth rates of *S. depressus* and calculated that sexual maturity is reached at 10–12 years old for males and 12–15 years old for females. Although little is known about *S. depressus* nesting habits, indications are that nesting

sites are typically located several meters from the shoreline in a sandy, vegetated area (Ernst *et al.* 1994; Dodd *et al.* 1988; Rogers and Marion 2004; USFWS 2009). Females are thought to produce up to two clutches per nesting season, with each clutch consisting of two or three eggs (Close 1982). Several factors can affect the survivability of these nests, such as fluctuating water levels and predation by raccoons, skunks (*Mephitis mephitis*) and foxes (*Urocyon cinereoargenteus*, *Vulpes vulpes*) (Ernst *et al.* 1994).

Sternotherus depressus prefers shallow, clear streams with substrate composed of large rocks and boulders with an abundance of crevices and submerged logs or vegetation, which it uses as protective cover (Ernst *et al.* 1994). Although it prefers streams, *S. depressus* can exist in lentic conditions when the shoreline provides favorable habitat (USFWS 2009). Unlike many other freshwater turtle species, *S. depressus* spends most of its time in the water, rarely basking in the sun (Marion and Bailey 2008; Dodd 1988).

Not known to be strong swimmers, *S. depressus* generally stays in favorable coves, avoiding movement across the wide, deep channels of the lake (Rogers and Marion 2004). Dodd *et al.* (1988) measured the movement of 13 individuals and found that males moved during 69 percent of the days they were monitored, while females moved only 50 percent of the days. Males also traveled greater distances (mean 31.2 m) than females did (mean 19.2 m). Most adult activity takes place at night, and increasingly so as the water warms during the summer (Ernst *et al.* 1994). Not much is known about the overwintering habits of *S. depressus* as its activity dwindles during the colder months (Dodd 2008; Melancon *et al.* 2011).

Little information exists about the lifespan of *S. depressus* in the wild. Few studies of *S. depressus* were performed before the construction of dams on the Black Warrior River, so the status of the turtle during the pre-dam era is unknown (Rogers and Marion 2004). Ernst *et al.*

(1994) speculate that some individuals surpass 20 years, while others estimate their lives to exceed 50 years in some cases (Rogers and Marion 2004; USFWS 2009). Predators and disease can affect the longevity of individuals. Predation on juveniles is thought to be high, thus many individuals do not reach sexual maturity (Ernst *et al.* 1989). Disease can also eliminate many individuals in a relatively short time period. A 1985 disease outbreak at a Sipsey Fork site was observed by Dodd (1988), who found 20 dead individuals along with others that showed obvious signs of disease (e.g., emaciation, lesions, discoloration, etc.).

To protect T&E species like *S. depressus* and to monitor other issues related to the construction and operation of dams, all hydroelectric projects must receive licenses from the Federal Energy Regulatory Commission (FERC) as authorized by the Federal Power Act. As part of its hydroelectric relicensing program, FERC can require the licensee to meet certain conditions regarding shoreline control, lake levels, and minimum flows. Other factors that are sometimes taken into consideration when issuing or reissuing licenses are services such as ensuring navigable conditions, encouraging public recreation (e.g., boat launches, public access areas, etc.), maintaining downstream flows (to sustain fish and endangered species), and flood control (maintaining capacity in reservoirs for heavy rainfall or flood-inducing events). Because the issuing of a license is an action taken by a federal agency that may impact various resources, care must be taken to ensure that any applicable laws and regulations are followed (e.g., the ESA, the National Historic Preservation Act, etc.). License applicants in Alabama must work closely with state and federal resource agencies whose responsibilities include carrying out these laws, such as the Alabama Department of Environmental Management (ADEM), the Alabama Historical Commission, the Alabama Department of Conservation and Natural Resources

(ADCNR), the U.S. Fish and Wildlife Service (USFWS), and the U.S. Army Corps of Engineers (USACE).

According to a SMP booklet detailing FERC guidelines, the organization applying for a hydroelectric license must take into consideration any species of concern that is known to live in the vicinity:

“In addition to having and understanding the project’s existing habitat, the licensee should be aware of the presence, or potential presence, of plant, animal, and fish species that are listed as threatened or endangered species, or are considered species of concern by federal or state agencies. The presence, or potential presence, of these species could have shoreline management implications.” (FERC 2001).

Therefore, it becomes imperative for the license applicant to have the means of monitoring shoreline activity. In most cases in Alabama, permits are needed for any new structures to be built along shorelines, or for existing structures to be substantially modified. These can include private and public piers, docks and boat ramps; marinas; water intakes and discharges; bulkheads; riprap or seawalls; developed beaches; portages; and recreational areas, among others. On Lewis Smith Lake (“Smith Lake”), Alabama Power Company (APC) is the permitting institution. Since *S. depressus* is known to inhabit parts of Smith Lake, actions that potentially affect the turtle directly or affect its habitat must be carefully regulated. Data regarding turtle whereabouts on the reservoir are needed to help make informed decisions regarding construction permits. Since Smith Lake has many miles of shoreline, comprehensive trapping of the reservoir is not feasible. An alternative method of data collection consists of classifying the shoreline of Smith Lake as likely or unlikely to house *S. depressus*. Ground-truth surveys would need to be conducted to ensure that the designated habitat reasonably agrees with the actual presence or absence of the turtles.

The purpose of this thesis is to evaluate the feasibility of using a habitat classification system prepared by an experienced *S. depressus* biologist to predict the distribution of a federally threatened species, the flattened musk turtle. If proven accurate, this classification system could be used in the permitting process for shoreline activity, which would significantly reduce the amount of time and manpower otherwise required.

CHAPTER 2

LITERATURE REVIEW

Endangered Species Geography

A study of an endangered species would not be effective without considering the condition and extent of its habitat. In their examination of 311 listed species' recovery plans, Foin *et al.* (1998) noticed that habitat reduction and habitat modification were the most commonly cited causes for species' listings. The principal cause for the original listing of the species can provide insight into which type of recovery program is warranted. Most recovery plans analyzed (63 percent) called for habitat restoration or active management, an indication that for many species simply preserving the existing habitat is not enough to promote a downlisting or population recovery (Foin *et al.* 1998).

Habitat fragmentation is a major factor in the listing of many species (Ewers and Didham 2006; Klemens 2000). Fragmentation of the landscape happens when overall suitable area is reduced or divided into discontinuous patches. This results from processes (mostly human-induced, Ewers and Didham 2006) such as fire suppression, invasion of exotic species, river alteration, and timber harvesting, among others. As suitable habitat shrinks and segregates, the original populations are forced into smaller areas, which increases density but stresses resources (Ewers and Didham 2006). These smaller patches are more susceptible to destructive events such as hurricanes, diseases, or fires that can wipe out dependent species and their habitat (USDA 1999; Ewers and Didham 2006). Particularly at risk are animals with limited mobility,

as well as larger species that have extensive habitat requirements. Habitat fragmentation can occur in both terrestrial and aquatic settings.

Impoundments are a common cause of habitat fragmentation in aquatic settings. Dams prevent many aquatic species from moving laterally along the river profile. Once populations become isolated above or between these impoundments they face challenges such as decreased genetic variation, loss of habitat and spawning or nesting sites, and increased risk of extirpation due to disaster. Migratory fish species face the challenges of accessing upstream spawning grounds and decreased genetic variation (Morita and Yamamoto 2002; Baxter 1977). As populations become isolated, either upstream or downstream of dam structures, they become vulnerable to demographic and environmental stochasticity. Because there is no immigration into these isolated communities, stochasticity and natural catastrophes have a more pronounced effect, and can cause extirpation. As habitat ranges become smaller due to fragmentation by impoundment or other reasons, the populations dependent on them have higher risks of extinction (Ewers and Didham 2006). Lakes and impoundments have been described as aquatic islands, and the theory of island biogeography can be applied in many cases (Baxter 1977; Keddy 1976).

Because turtles typically experience delayed sexual maturation and can have low nesting success, any interference to their life history, including removal by collection or habitat destruction, can have pronounced effects (Klemens 2000; Rizkalla and Swihart 2006; Close 1982; Congdon *et al.* 1993; Heppell 1998). Turtles have relatively long life spans, therefore the effects of habitat alteration and fragmentation could experience a lag, not becoming apparent until years after initial disturbance (Browne and Hecnar 2007). For instance, Howeth *et al.*

(2008) suggest that the loss of genetic diversity due to habitat fragmentation can experience a lag within turtle populations because of their long life spans.

Management and Planning

Many of today's current stream management practices have profound effects on the surrounding wildlife. This includes not only the aquatic organisms, but also those which live in or use the riparian zone adjacent to the stream channel. A total of 25,000 miles of U.S. waterways are maintained and operated for commercial navigation (U.S. Army Corps of Engineers 2010). Regulation of these waterways provides many benefits for society, such as increased commerce, hydropower, and flood regulation (Baxter 1977). However, these benefits often have environmental side effects, such as loss of species diversity and habitat alteration. Management decisions, especially those made by government agencies such as FERC, are expected to give equal consideration to both developmental and environmental values.

Humans use rivers for many purposes including irrigation, transportation, recreation, electricity generation, and consumption, among others. To maximize the stream's potential for these purposes a variety of management practices are used.

- Removal of logjams and woody debris from streams often occurs for both navigation and commercial purposes. These logs and vegetative debris are an integral part of the stream ecosystem, providing cover for many organisms, including freshwater turtles (Klemens 2000; Lindeman 1999). Also, their removal alters the geomorphic processes of the stream and disturbs benthic organisms. Many states have recently begun requiring permits to remove these "deadhead" logs from rivers. As submerged logs and vegetation along the

shoreline are removed, suitable habitat for turtles, especially species which are poor swimmers and thus rely on abundant cover, becomes fragmented. (Kaesar and Litts 2008).

- Construction of canals and levees in order to drain riparian areas alters prime turtle habitat. Many species rely on the floodplain wetlands at different stages of their lifecycles. Wetlands, with their shallow, fertile habitats, can be a great environment for juvenile turtles. The degradation of the wetland habitat can lead to a loss of species diversity not just with turtles, but with other types of organisms as well.
- Channelization, similar to riparian draining, can also lead to habitat loss and changes in species composition. Stream channelization is used for purposes such as agriculture, irrigation, and flood control. The changes that occur due to channelization can lead to a reduction in food resources, changes in species composition, and habitat loss. Instead of having varying flow patterns that can support different life forms (Baxter 1977), channelized streams are homogenized. Some turtle species cannot cross channelized streams due to the increased flow velocity of the channel. This could lead to isolation of populations. Also, dredging associated with channelization can disturb benthic organisms. (Bodie 2001).
- Impoundments can have many effects on freshwater fish and invertebrates (Baxter 1977; De Jalon *et al.* 1994; Erman 1973; Quinn and Kwak 2003; Cushman 1985; Kadlec 1962). Impoundments cause a drastic and immediate change in the entire stream ecosystem. They can cause isolation and population fragmentation, as

areas of once-favorable habitat become submerged or are separated by large sections of now-unsuitable habitat (Klemens 2000). The reservoirs created by these dams typically cater to lentic species and decrease habitat diversity.

Impoundments also greatly affect seasonal changes in water levels and flow patterns, which can in turn affect access to nesting sites for aquatic turtles. Many species prefer to nest on sandbars, which can be eliminated by channelization and impoundment.

- Pollution and siltation are two major problems facing many river systems today that stem from river and land management practices. Degradation of water quality can be tied to increased industry, agricultural runoff, and urbanization. Siltation, which can be caused by vegetation removal, construction, and impoundments, can alter the stream bed, filling in pools and eventually even reservoirs. Fine silt can clog crevices, which *S. depressus* in particular relies on for cover and protection (Dodd *et al.* 1988). Also, serious siltation can displace many benthic macroinvertebrates that turtles and other animals rely on for food. The degree of siltation on a stream bed has been directly correlated with the amount of food available (Berkman and Rabeni 1987; Lemly 1982).
- Collection of turtles by humans for medicinal purposes, as a food source, or as pets has directly affected the viability of many turtle populations worldwide. Because of the pressure of collection, both legal and illegal, many populations face eradication. Turtles have relatively long lives, and do not reach reproductive age for several years. Some species, such as *S. depressus*, lay 1–2 clutches of eggs per season, each typically containing only 2–3 eggs (Close 1982). Because

of these reproductive and maturation characteristics, removal by collection has a strong impact on population dynamics (Klemens 2000). Congdon *et al.* (1994) studied the reproductive and survival trends of common snapping turtles (*Chelydra serpentina*) in Michigan, focusing on the additional pressure that hunting brings to a population with an already-slow reproductive rate. Congdon *et al.* (1994) concluded that management programs, in order to be successful, must recognize the importance of protecting all life stages of long-lived organisms. Turtles' shells offer a degree of protection, but only after reaching a certain size threshold (Klemens 2000). Because of the importance of this protective mechanism, young turtles allocate resources to shell development, which delays sexual maturation to a later age. This phenomenon often results in higher survival rates for older, larger turtles.

Bodie (2001) suggests riparian management practices to protect these areas that are home to such a wide array of organisms, including mammals, birds, reptiles, fish, invertebrates, and plants, among others. He proposes that a 150-meter riparian zone is needed to help ensure turtles have a sufficient nesting area. Bodie calls for monitoring of collection, and encourages documentation of turtle populations by researchers. An adequate amount of research and population data is vitally important for the creation of relevant species recovery programs. Little information exists concerning many listed species, especially regarding population demographics prior to being listed under the ESA.

The ESA has not been without controversy since its implementation in 1973. Environmental goals often clash with economic development. One of the most well-known cases of conflict involving stream management was the Tennessee Valley Authority's (TVA's)

Tellico Dam project on the Little River in eastern Tennessee. Construction on Tellico Dam, a multimillion-dollar project aimed at flood control, hydroelectric generation, and recreation, began in 1966. In 1973, the snail darter (*Percina tanasi*) was discovered upstream of the dam construction site. In 1975, the species was listed as endangered under the newly enacted ESA. Environmental groups sought a court injunction to cease the construction on the dam, as its completion would in effect destroy the habitat of the small fish. The legal case worked its way up through the federal court system, eventually reaching the U.S. Supreme Court, which affirmed the U.S. Court of Appeals' decision to issue an injunction ceasing construction of the nearly completed Tellico Dam. Congress was not pleased with the ruling, as the dam was expected to boost the economy and provide electricity, and millions of dollars had already been spent on the project. While continuing to designate funding for the dam construction, Congress began drafting legislation providing an exemption for Tellico Dam. Critics of the injunction argued that the ESA was not meant to be carried out to this extreme—the abandonment of an underway project that was projected to have a large regional impact economically and developmentally. The ESA provided no loopholes for cases such as Tellico Dam. In 1979, Congress added amendments to the ESA establishing and authorizing an interagency panel to review individual cases for exemptions from parts of the ESA. However, this panel denied the Tellico Dam project an exemption based on their belief that the project was “ill-conceived and uneconomic”. Later the same year a provision authorizing the completion of the dam was passed as a rider attached to an omnibus public works bill. The snail darter was downlisted in 1984 from endangered status to threatened status. In a more recent study, Ashton and Layzer (2008) sampled nine streams in which *P. tanasi* had previously been found. Of these nine streams, the French Broad and Hiwassee rivers contained the largest populations, including both young and

older individuals. These two rivers produced 365 of the 384 (95 percent) *P. tanasi* either observed or collected in this study (Ashton and Layzer 2008). The remaining 19 (5 percent) individuals were dispersed among five streams, while two streams produced no *P. tanasi* specimens (Ashton and Layzer 2008). (Yaffee 1982; Ono *et al.* 1983).

Table 2.1 Timeline of the Tellico Dam project

Year	Action
1930s	Tellico Dam first proposed, determined to be not economically feasible
1942	Tellico Dam reconsidered, plans postponed for World War II
1963	Third proposal for Tellico Dam construction at cost of \$41M
1966	Congress approves construction of Tellico Dam
1969	National Environmental Policy Act (NEPA) passed
1971	Suit seeking injunction brought against TVA for not preparing an environmental impact statement (EIS)
1973	Federal court dismisses injunction after review of EIS
1973	ESA signed by Nixon, no known T&E species in dam area
1973	Snail darter discovered in Little Tennessee River (LTR)
1974	Report on snail darter submitted to USFWS
1975	Petition for federal listing of the snail darter
1975	TVA begins to transplant the snail darter to the Hiwassee River
1975	Snail darter listed as endangered, critical habitat designated, including portions affected by dam
1976	Permanent injunction sought against Tellico Dam for violation of ESA
1976	District court denies injunction
1977	U.S. Court of Appeals reverses district court decision, issues injunction
1977	Jimmy Carter elected U.S. president
1978	U.S. Supreme Court upheld injunction issued by Court of Appeals
1978	Congress amends ESA, creates an Exemption Committee
1979	Exemption Committee unanimously votes against Tellico Dam exemption
1979	Short amendment exempting Tellico Dam from federal laws is attached to existing energy legislation and passes Congress without debate
1979	Carter signs legislation including Tellico Dam exemption amendment
1980	Tellico Dam gates close; LTR floods
1984	Snail darter is downlisted from "endangered" to "threatened"

Development in the past 100 years has created many challenges for planners and conservationists as landscapes have changed and natural resources have been harnessed. The fact that these resources and habitats rarely adhere to political boundaries often presents a challenge to resource managers. Management goals are difficult to accomplish without the support of neighboring areas. Many vulnerable, “restricted-range” species occur along the southern U.S. border. Abbitt *et al.* (2000) examined areas in the U.S. with high numbers of these “restricted-range” species of butterflies and birds. These include species which occur in only a few counties, or which have a relatively small breeding range. The smaller a species’ geographic range is, the more vulnerable it becomes to extinction due to habitat destruction (Ewers and Didham 2006). In addition, the authors identified a significant overlap between the occurrence of these restricted-range species and areas of high projected human development. These areas are inherently important to restricted-range fauna, but are expected to experience an increase in human population density. Although many of the species identified are not listed as federally threatened or endangered, they have a high risk of becoming so due to the small size of their range. Abbitt *et al.* (2000) suggest that restricted-range species be considered in future habitat conservation plans (HCPs).

Another challenge of endangered species conservation and management is funding. Conservation efforts and funding are often guided by factors such as species rarity, as well as species popularity. These management efforts often take an individual-species approach, with half of the federal funding being designated to the conservation of about 1 percent of the listed species, such as the grizzly bear (*Ursus arctos*), bald eagle (*Haliaeetus leucocephalus*), and peregrine falcon (*Falco peregrinus*), among others (Flather *et al.* 1998). Flather *et al.* (1998) suggest that efforts would be better spent focusing on conservation of critical ecosystems rather

than specific species. Flather *et al.* (1998) identified endangered species “hot spots”, or areas in which these listed species tend to be clustered. These endangerment “hot spots” were then compared with the ranges of species that receive the most federal funding for T&E species conservation programs. If the high-expenditure species’ ranges overlap these “hot spots”, then they can be a sort of “umbrella species” which provide protection to others they share the habitat with. However, some of the high-expenditure species whose ranges most often overlap the “hot spots” have very large ranges, most of which lay outside of the “hot spots”. Flather *et al.* (1998) suggest that identification of T&E species concentrations and the critical habitats and ecosystem processes involved in these areas be taken into consideration for habitat conservation in order to protect the most T&E species with the available federal funding.

Turtle Behavior

Turtle behavior is influenced by many environmental factors, both natural and human induced. Marchand and Litvaitis (2004) examined the factors that affect the population structure of the painted turtle (*Chrysemys picta*), a common aquatic turtle. Many of the variables they considered are indicative of landscape development, such as road proximity to habitat and abundance of forestland and vegetation. These factors, as well as characteristics such as pond substrate, adequate nesting habitat, distance to wetland, and shoreline vegetation can affect demographics such as turtle abundance, sex ratio, and age distribution of the population. Marchand and Litvaitis (2004) found that ponds located in areas with greater road density nearby tended to support a higher population of males than females, thought to be because females are at greater risk of being killed by automobile traffic as they search terrestrial habitat for suitable nesting sites.

The presence of dams can alter some of these environmental factors both upstream and downstream of the structures. Many of the affected features, such as sedimentation, water velocity, water temperature and canopy cover, can in turn affect the organisms within those streams. Reese and Welsh (1998) looked at the distribution of western pond turtles in relation to habitat variables affected or unaffected by the damming of the Trinity River in California. Overall, the habitat of the mainstem (dammed) was believed to be more homogenous than the south fork (undammed). Upon observation, the mainstem had a greater range of depths, canopy cover, basking sites, and undercuts, while the south fork had a greater range of flow types and water temperatures. Discriminant analysis (DA) showed that turtle-present quadrats could be distinguished from random quadrats based on variables such as river transect, underwater cover, canopy cover, small basking sites, water temperature, flow type, maximum water depth, and maximum bank undercut. Turtles were more often present in sites with lower water velocities, deeper water, and more abundant underwater cover.

There are also natural conditions that affect the distribution and behavior of freshwater turtles. The Fall Line serves as a natural barrier for not only turtles, but many other aquatic species as well (Buhlmann *et al.* 2008; Tinkle 1959; Moll and Moll 2004). The Fall Line is the area of transition between the upland Piedmont region and the lowland Coastal Plain region in the Southeast and is usually marked by rapids or waterfalls. Because many aquatic organisms cannot navigate past a waterfall or rocky shoals, their distribution is limited to streams above or below the Fall Line. The stream conditions also differ between the Piedmont and Coastal Plain regions because of the difference in substrate material. The Piedmont is underlain by bedrock material, while the Coastal Plain is made of sedimentary material.

The substrate material and its configuration can have a significant role in turtle location and behavior as well. Jackson (1988) conducted a study regarding crevice occupation by southeastern musk turtles. Three experiments took place, testing the turtles' attitude toward light, tactile features and size of artificial crevices. Jackson (1998) used a chi-square test to examine preferences among crevice type. The individuals in the study spent more time in the crevices during the day rather than at night. There seemed to be a preference for both dark crevices, and "touchable" crevices (crevices with ceilings low enough to touch the carapace when occupied). However, when the turtles had to choose either a dark, untouchable crevice or a lighter, touchable crevice, they chose the touchable feature above the dark crevice. Jackson (1998) concluded that musk turtles are not photophobic, but see the dark crevices as a sign of crevice height. They are attracted to crevices for the protection they provide from predators.

Protective cover can also influence turtle movement on land. Jennings (2007) studied the difference in microhabitat selection between adult and juvenile Florida box turtles (*Terrapene carolina bauri*) on Egmont Key. Juvenile box turtles showed a preference for palm pepper forest habitat, while adult turtles used this habitat as well as others. When smaller and more vulnerable in the juvenile stage, turtles require a greater degree of protection from predators by their habitat. In addition to protection from predators, other functions of habitat include food and protection from the physical environment (Jennings 2007). The requirement for all of these functions can change as the turtle grows or changes life stages (Klemens 2000), therefore its habitat preferences can change. Thus, if an area contains an abundance of adult-preferred habitat conditions, but lacks areas that cater to juvenile habitat needs, recruitment in that population could be negatively affected. Change in habitat preference can also occur with change in habitat composition through time. As in the case of the Florida box turtle, the preferred habitat, palm

pepper forest, includes an abundance of introduced vegetation in the form of Brazilian pepper (*Schinus terebinthifolius*). Jennings (2007) cautions that removal of this non-native vegetation could be detrimental to the box turtle population if not done gradually and replaced by native plants with similar characteristics, as they seem to have adapted to and show a preference for the species.

Flattened Musk Turtle: Prior Studies

A number of biologists and researchers have conducted studies of *S. depressus* since its description as a species by Tinkle in 1955. These studies have examined topics such as genetics, disease, fragmentation, human impact, distribution, and population status changes. Most *S. depressus* studies have considered their full range, not just the Smith Lake environment, as *S. depressus* prefers the stream environment.

Iverson (1977) conducted a study on the phenetics of the musk turtles in Southeastern streams. *Sternotherus depressus* inhabits the Black Warrior River Basin above the Fall Line, while its congener, *Sternotherus minor*, has a range that extends to just above the Fall Line. Iverson (1977) attributes this mutual occurrence and presence of apparent hybrids to the breakdown of isolating barriers, which was caused by relatively recent impoundments. This raising and regulation of the water level joined the two reaches, which were previously separated by the fast-moving, rocky stretches of the Fall Line which the turtles were unable to cross.

In a 1990 study, Dodd examined the effects of habitat fragmentation on *S. depressus* populations in the Black Warrior River Basin above Bankhead Dam. According to Dodd (1990), the three main sources of habitat fragmentation in the Black Warrior River Basin are sedimentation, impoundments, and pollution. Sedimentation can directly affect *S. depressus*

populations by clogging crevices which are used for hiding and protection, or indirectly, by reducing the mollusk population, an important food source for *S. depressus* (Dodd *et al.* 1988). Impoundments create deep, lentic environments which separate suitable habitat reaches. Dodd (1990) states that it is unlikely that *S. depressus* could navigate the extensive, deep waters of reservoirs, or successfully find their way around the dam structures. He lists the potential challenges to *S. depressus* populations brought on by habitat fragmentation, including loss of genetic viability; abnormal population structure such as skewed sex ratios or preponderance of older individuals; susceptibility to disease; and loss of individuals due to illegal collecting. In conclusion, Dodd (1990) notes the challenge of today's habitat fragmentation is that it results from direct human modification, and the effects can be seen in a relatively short time period, which does not give the species much time to adapt to changing conditions.

In addition to habitat fragmentation, humans also affect other aspects of stream ecology. Bailey and Guyer (1998) examined human impact on *S. depressus* demography and population status. The degree of human impact was measured by variables such as area land use, substrate type, and water quality parameters such as stream turbidity, silt accumulation and algae. In addition to using data from prior studies, six sites were chosen for this two-year study: three "impacted" sites and three "unimpacted" sites. Turtle data were gathered and organized to assess the difference between impacted and unimpacted sites based on population density, sex ratio, and size distribution. Physical health was also assessed using relative body mass, leech parasitism, and shell damage. A total of 343 captures were made over 3,035 trap days for a turtles-per-trap-day rate of 0.113 (Bailey and Guyer 1998). Turtle captures per trap day differed significantly between sites, measuring 0.0128 at impacted sites and 0.2090 at unimpacted sites. Impacted sites were also skewed toward larger individuals. Regarding physical health characteristics,

relative body mass and frequency of shell damage did not differ significantly between site types, while the presence of leeches (*Placobdella parasitica*) usually found on healthy turtles was significantly greater at unimpacted sites (Bailey and Guyer 1998, Dodd 1988). Population density was examined by looking at the number of turtle captures per trap day, which was significantly less at the impacted site when compared to the unimpacted site; however, the sample size (n=19) of turtles captured at the impacted site was not sufficient to make any conclusive statements (Bailey and Guyer 1998). In comparisons with prior studies (Dodd *et al.* 1988; Dodd 1988), the population estimates were similar, but a decline in rate of turtle capture was seen. Bailey and Guyer (1998) expected *S. depressus* populations at the impacted sites to become extirpated due to the apparent absence of recruitment.

Population decline can also be affected by disease rates. Dodd (1988) conducted a follow-up study in 1986 based on a 1985 survey (Dodd 1986) in which the *S. depressus* population of the Sipsey Fork seemed to be struck with disease. This epidemic appeared to cause the population of the study area to decline by 50 percent during the summer of 1985. However, the 1986 survey showed no additional population decline, and some turtles showed signs of recovery from previous illness. Fewer turtles were observed basking in the 1986 survey, a behavior that is associated with poor health and weakened immune systems (Dodd 1998; Marion and Bailey 2008). Basking may serve to raise the body temperature of *S. depressus* as a way of boosting its immune system to fight against bacterial infection as suggested by Mount (1981). Dodd (1988) also examined turtles that appeared diseased in both study years. Ten of the 44 individuals captured in an early September 1985, sampling event showed obvious signs of disease, which included emaciation, lesions on the plastron, discolored carapace, eroded marginals, swollen eyes, pale faces, a lack of leeches, or increased basking behavior. During

July–September, 1985, 20 dead *S. depressus* were found in the study area while wading. Other turtle species found during this study showed no signs of disease. In the 1986 survey, 19 of the 153 individuals found showed disease symptoms, but none as severe as in the prior study. Also during the 1986 survey, 26 individuals were found that appeared to have recovered from prior illness. Overall, Dodd concluded that the *S. depressus* population appeared to be recovering from the disease outbreak of 1985; however, the overall trap capture ratios declined steadily from previous studies (Ernst *et al.* 1983; Dodd *et al.* 1986; Dodd *et al.* 1988). One hypothesis given was the suspicion of illegal collecting, which could have removed as many as 200 *S. depressus* from the Sipsey Fork in the summer of 1985 (Dodd *et al.* 1988).

A few *S. depressus* studies focus on specific areas of interest within the Black Warrior River Basin. Rogers and Marion (2004) researched the population status of *S. depressus* in two branches of Smith Lake, located in the upper reaches of the reservoir. Their trapping effort produced a total of 59 specimens, with a success rate of 0.42 turtles per trap night. The success rate for the Sipsey Fork branch was 0.52 turtles per trap night, while the success rate for the Brushy Creek branch was 0.29 turtles per trap night. They compared their trapping data with prior studies conducted in the early 1980s which included portions of Smith Lake in the study areas. Mount's 1981 study in the Sipsey Fork branch produced a success rate of 0.75 turtles per trap night, higher than Rogers and Marion's 0.52 per trap night in 2004. Ernst *et al.* (1983) trapped in both the Sipsey Fork and Brushy Creek branches, where they incurred success rates of 0.25 and 1.3 turtles per trap night, respectively. However, these 1980s studies were based on low numbers of traps set, complicating comparison to the 2004 Rogers and Marion study. Rogers and Marion (2004) also examined the size class distribution of the turtles caught, and concluded that fewer turtles from the smaller size classes were found in Smith Lake when

compared to nearby stream sites, indicating that juvenile recruitment in the reservoir may be suffering. Possible explanations for this lack of recruitment in the lacustrine environment include fewer favorable nesting sites, an increased number in predators (targeting both juveniles and eggs), and the potential effects of seasonal drawdown.

Bailey and Bailey (2003) performed a study in which they observed the population and habitat utilization of Smith Lake by *S. depressus*. A total of 20 locations were chosen in sites that appeared favorable for *S. depressus* colonization—those with an abundance of rock crevices or nearby logs. Each trap was deployed at least a half-mile from any other trap. This study included all three major “stems” of the lake. Eight individuals were caught at three study sites. Unlike the Rogers and Marion (2004) study, Bailey and Bailey (2003) found a wide size-class distribution among their specimens, with carapace lengths ranging from 43.8–92.6 mm. The capture rate for this study was 0.028 turtles per trap night overall, with a 0.2 turtles per trap night rate among the Ryan Creek sites. Bailey and Bailey (2003) described Smith Lake as a patchwork of suitable habitat for *S. depressus*. The Smith Lake shoreline is interspersed with favorable (riverine coves and rocky shoreline) and marginal to unfavorable (lack of rocks or logs, heavy mud or silt layers on the substrate) shoreline habitat.

CHAPTER 3

METHODS

Study Area

Alabama is well known for its species diversity, ranking fifth in the U.S. in overall biodiversity (Stein 2002). Much of Alabama's species diversity is due to the abundance of freshwater streams. With 77,000 miles of waterways for habitat, Alabama ranks first in the U.S. for the number of freshwater fish species and first in the world for the number of freshwater mussel species (Stein 2002). This species diversity of aquatic organisms is also due in part to the fact that many river systems within the state traverse a variety of ecosystems and geomorphologic structures, with streams beginning in the upland, Appalachian terrain and draining through the more sedimentary Coastal Plain into the Gulf of Mexico (Lydeard and Mayden 1995). The markedly different conditions of these streams allow for the existence of creatures with different habitat preferences. This abundance of freshwater species in the state is reflected in Alabama's endangered species listings, where 74 of the 92 federally threatened or endangered animal species are associated with freshwater ecosystems. Flather *et al.* (1998) identified the Southern Appalachians region as one of 12 "hot spots" of T&E species in the conterminous U.S. In this region, nearly 75 percent of the listed species were associated with aquatic systems (Flather *et al.* 1998). In examining the factors contributing to the listings of these species, Flather *et al.* (1998, 370) found that the most commonly cited was contamination

and modification of aquatic environments stemming from mining, reservoir construction, and farming, which affected half of the listed species in the Southern Appalachian region.

Located in northern Alabama, Smith Lake was formed by the construction of Lewis Smith Dam on the Sipsey Fork of the Black Warrior River, which began in 1957 and was completed in 1961 (Figure 3.1). Smith Lake was created not only for power generation purposes, but also to improve navigation downstream, as it provides a source of flow during the drier months. Smith Dam, which cost \$29 million to build, is the largest earthen dam in the eastern United States. The dam is filled with rocks and earth, and stretches 2,200 feet long by 300 feet high. At full pool (510 feet above msl) this reservoir covers more than 21,000 acres and has more than 500 miles of shoreline.

Smith Lake, with portions in Walker, Winston and Cullman counties, is known for its deep water. The deepest part of the lake, in the forebay of the dam, measures 254 feet deep. Smith Lake has three main “stems” or creeks—Ryan Creek on the eastern side, Rock Creek in the center, and the Sipsey Fork on the western side. Smaller creeks (Clear Creek, Brushy Creek, Simpson Creek, etc.) branch off these main stems.

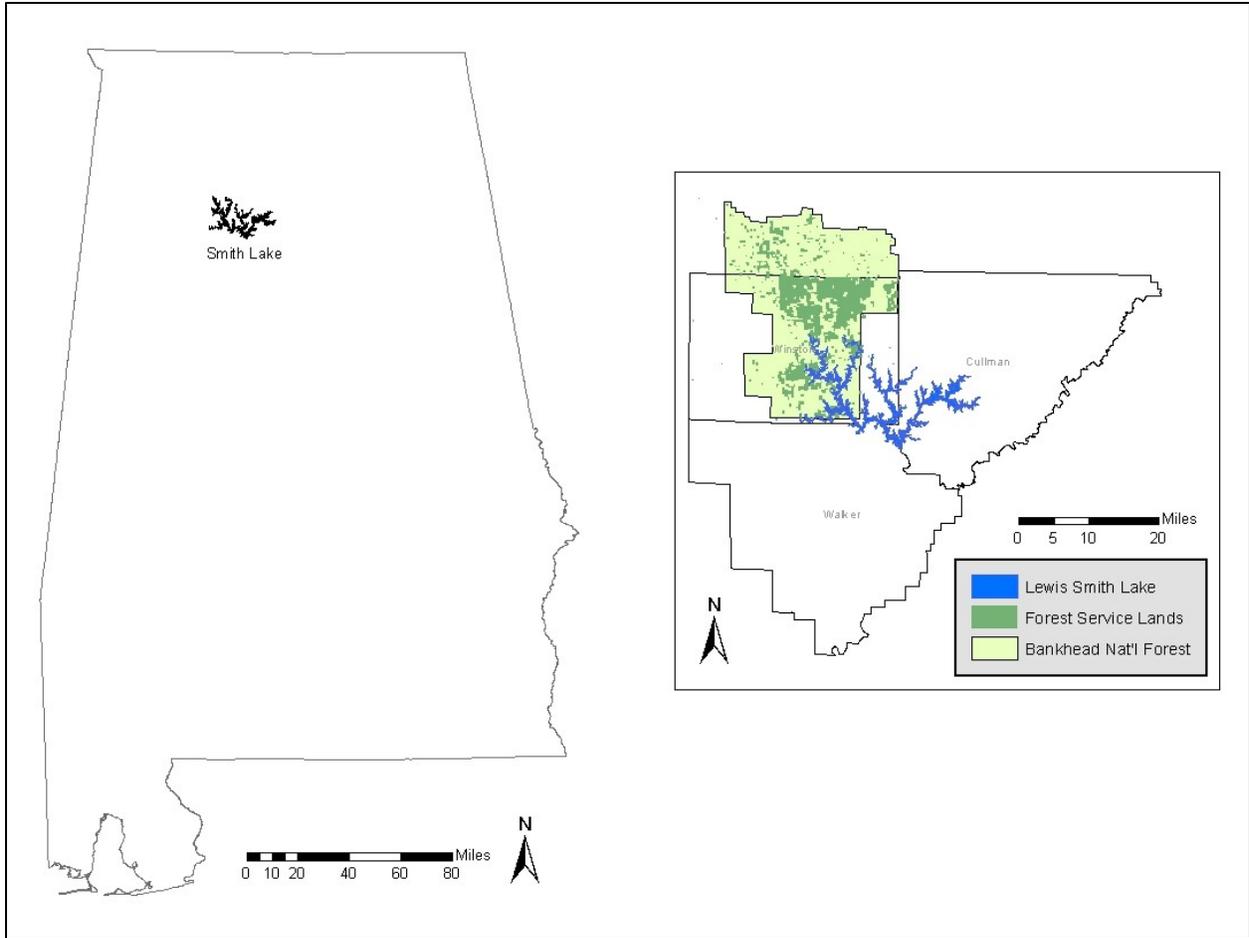


Figure 3.1 Smith Lake, in northern Alabama

Smith Lake is located within the Black Warrior River Basin, which drains 6,392 square miles, 12 percent of Alabama’s land area. Three main tributaries—the Mulberry Fork, the Sipsey Fork and the Locust Fork—converge to form the Black Warrior River. This watershed is underlain by the Warrior Coal Field, a large coal reserve that is 2,000 feet thick in some places and covers about 4,000 square miles. The coal that makes up the Warrior Coal Field is high-grade, bituminous coal and has been mined commercially since the mid-19th century. The location of the Black Warrior River is essential to the coal industry, as it provides a

transportation option for coal-laden barges. Abandoned mines in the area present a water quality challenge, as they become sources of siltation and pollution from runoff. Acid mine drainage is common in areas with extensive past or current coal mining, and occurs when unweathered rocks or minerals containing iron sulfide become exposed to the atmosphere (ADEM 2005). When rainfall or runoff flows across these exposed surfaces, oxidation occurs and sulfuric acid is formed and various metals are released into the runoff water (ADEM 2005). Once the acid drainage enters a stream, it alters the water chemistry by lowering the pH; destroying or reducing natural alkalinity; increasing total hardness; producing excessive amounts of iron, manganese, aluminum, and sulfate; and raises specific conductance (ADEM 2005). These changes negatively affect both man-made structures (corrosion shortens life span) as well as naturally occurring flora and fauna (ADEM 2005).

Smith Lake sits in the Southwestern Appalachians ecoregion, which ranges from 250 feet above msl to about 1,100 feet above msl, and is characterized by open, low mountains with forest and woodland with some pasture (Alabama Water Watch 2005; Black Warrior River Watershed Management Plan 2005). The streams in this region are mostly of moderate gradient and have substrates of cobble, gravel, and bedrock. The climate of this region is humid subtropical, where the mild winters and moist, hot summers cater to the high biodiversity of plants and animals found in this region (Christopherson 2007; Knight 2007).

Recreational activity supported by Smith Lake includes canoeing, kayaking, swimming, fishing, hunting, camping, and pleasure boating. Annual recreational use of Smith Lake in 1994–1995 was estimated at 1,539,759 person-hours of recreational activity (Feldman 2008). A 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation reported that overall economic benefits of freshwater fishing in Alabama totaled \$1.2 billion. According to

ADCNR (2008), more than 1 million boaters use Alabama's lakes, rivers and coastal areas annually.

Given the above statistics, the local economy is greatly impacted by the lake. In 2008, Smith Lake had more than 8,800 privately owned properties, which, including the land, were valued in excess of \$1.8 billion. Property taxes for Smith Lake properties were estimated at \$5.8 million for the year 2007. In addition, Smith Lake generated \$88 million in revenues for nearby businesses. (Feldman 2008). Thus it represents a center for outdoor recreation and the economic benefits that result. However, development associated with recreation also threatens certain species such as the turtle.

Habitat Classification

As the shoreline of Smith Lake is used by humans in many places for recreational purposes (i.e., boat ramps, docks, marinas, seawalls, etc.), it becomes important to minimize the impact of shoreline alteration on the habitat of the federally threatened *S. depressus*. In order to determine which shoreline segments are used by *S. depressus*, a habitat classification system was developed in 2010–2011 by a team of biologists (APC and independent). For referencing purposes, Smith Lake was divided into 491 tiles, each containing 216.9 acres (Figure 3.2). An aerial photograph of each tile was printed and overlaid with a contour line delineating the shoreline at full pool (510 feet above msl).

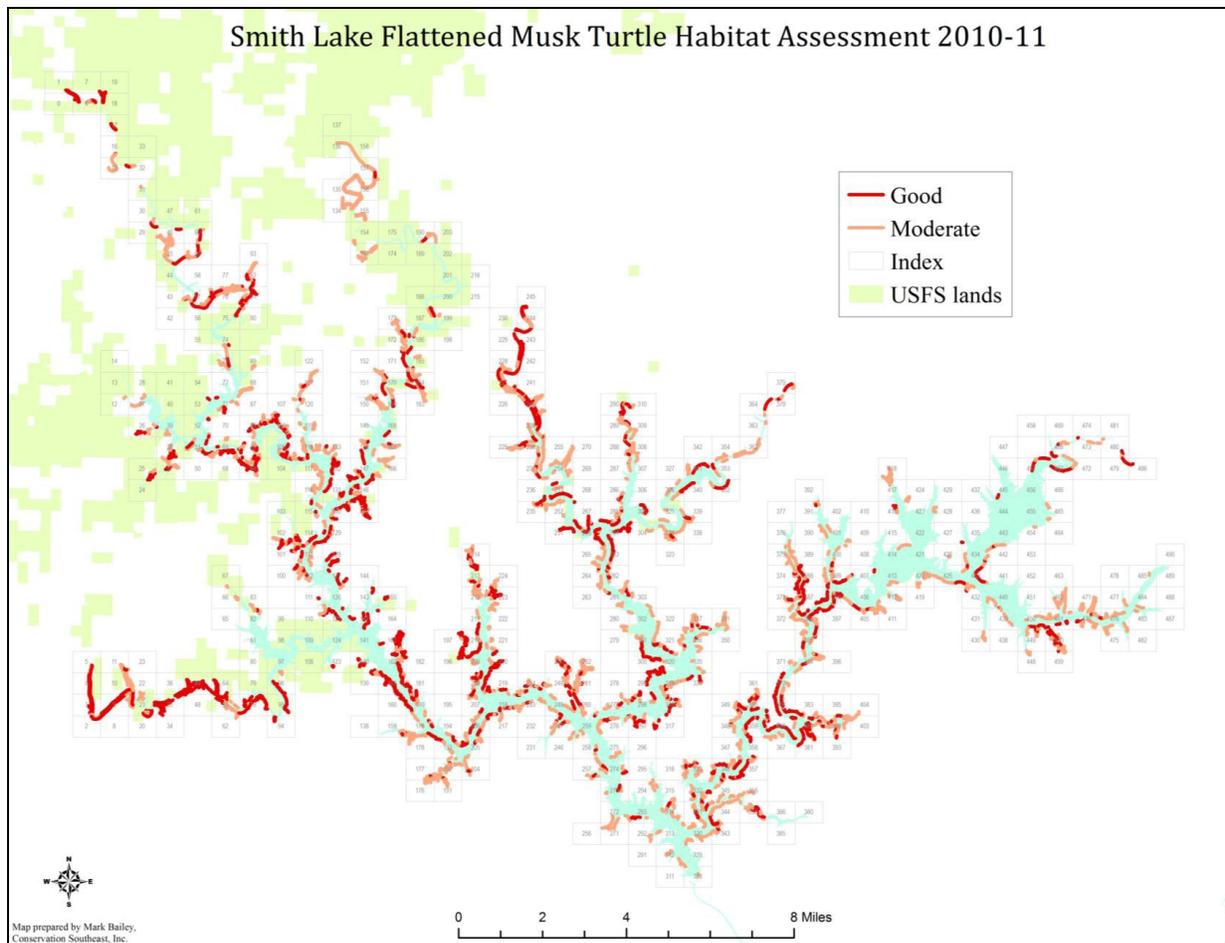


Figure 3.2 A total of 491 reference tiles represent all of the shoreline of Smith Lake.

During September and October 2010, a biologist extensively familiar with *S. depressus* visually assessed much of the shoreline, using designations of “Good”, “Moderate”, “Poor”, and “Bluff” to describe the shoreline habitat relative to adult *S. depressus* preference (Figure 3.3). This assessment was based primarily on the substrate and bank type, which could be easily observed because of the lower water level. The designations were marked on the shoreline of the reference tiles during field observation. These field notes were used to create a geographic information system (GIS) shapefile by clipping the 510-foot contour line into segments by habitat designation.

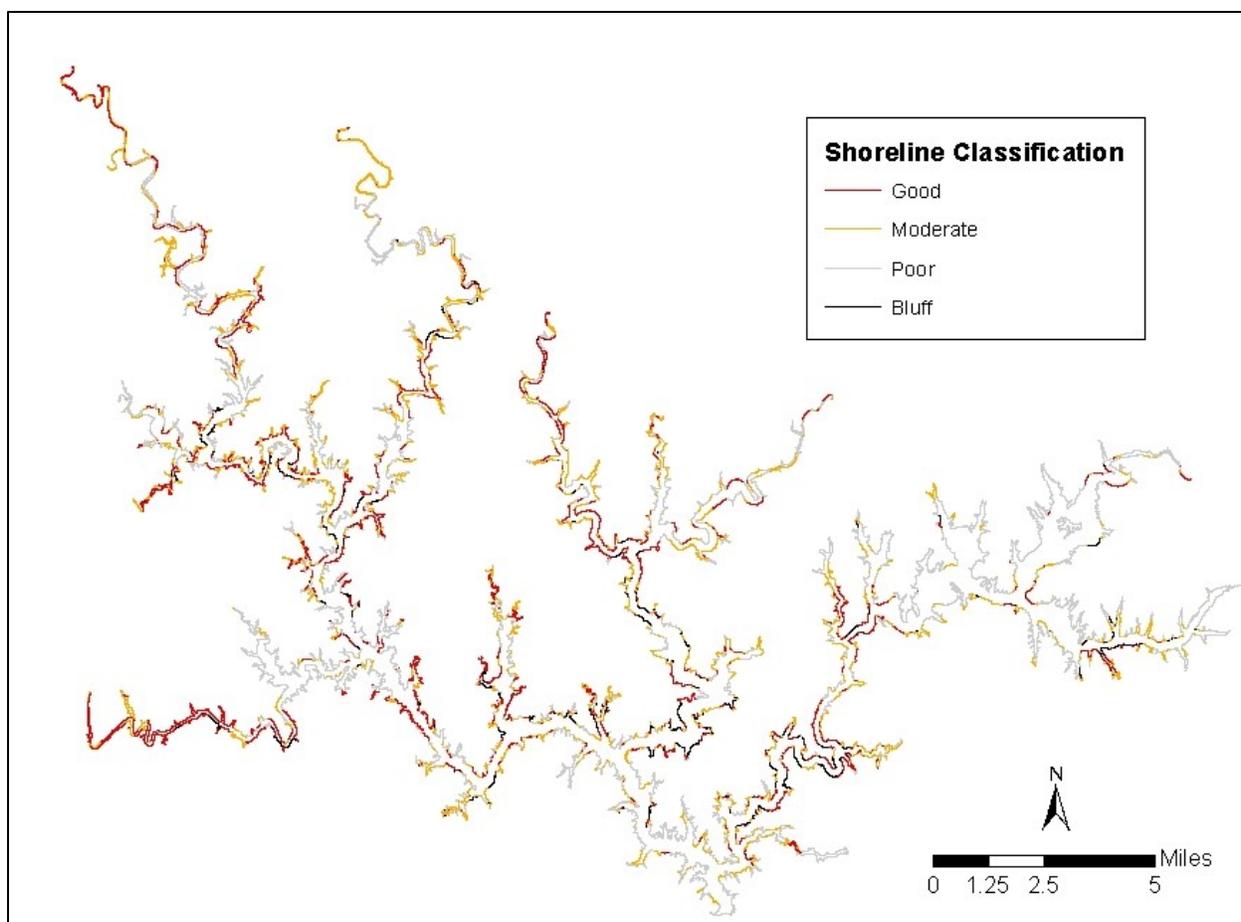


Figure 3.3 Smith Lake shoreline classification map

Shoreline that had an abundance (i.e., continuous or near-continuous distribution) of large (>24-inch) rocks and crevices was labeled as “Good” habitat (Figure 3.4). These were areas likely to support an *S. depressus* population and had little exposed soil or siltation, mostly underlain by bedrock slabs. “Moderate” habitat consisted of stretches that contained some rock, but they were either smaller or more spread out than “Good” habitat, and had limited crevice structures (Figure 3.5). “Poor” habitat was typically composed of smaller rock, gravel, and cobble, and lacked crevices (Figure 3.6). Also included in the “Poor” category were segments with bare soil or riprap. Vertical or near-vertical rock bluffs were categorized as “Bluff” on the habitat map if there was no visible indication of good habitat features at the base of the bluff,

such as protruding rocks, crevices, or sloping bottoms (Figure 3.7). No traps were placed along “Bluff” segments. All shoreline classification was performed by the same person; however, the nature of the classification process was necessarily subjective, so some degree of overlap is to be expected. For example, the low end of “Good” habitat and the high end of “Moderate” habitat may overlap in the state of their substrate conditions.



Figure 3.4 An example of “Good” habitat. (There is an abundance of large rocks and crevices in this exceptionally good habitat.) (Source: Alabama Power Company)



Figure 3.5 An example of “Moderate” habitat. (Although this shoreline is underlain by bedrock slab, it does not provide ample cover or crevices, and lacks an abundance of large rocks.) (Source: Alabama Power Company)

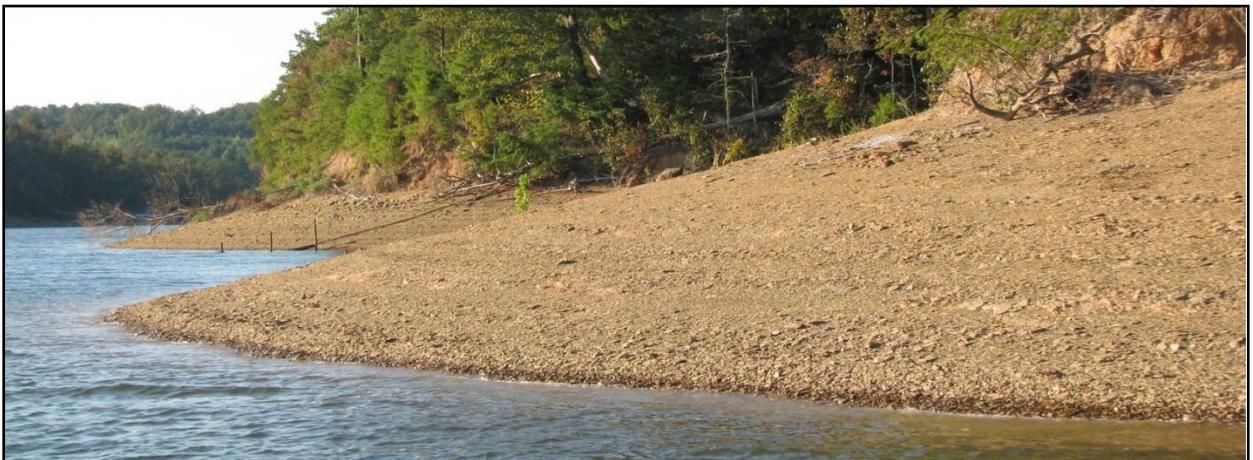


Figure 3.6 An example of “Poor” habitat. (This stretch of fine cobble provides no suitable *S. depressus* habitat.) (Source: Alabama Power Company)



Figure 3.7 An example of “Bluff” habitat. (These vertical bluffs are in deep water year round and provide no suitable *S. depressus* habitat.) (Source: Alabama Power Company)

Trapping

Trapping sites were randomly selected by APC field biologists in each of the three habitat types to provide a ground-truth assessment of the habitat classification. I was able to provide field assistance during some of the spring 2012 sampling trips. We set each site with 10 collapsible traps baited with raw chicken wings. Traps were anchored to bank material (e.g., trees, shrubs, roots) with twine and set on flat surfaces in 1–5 foot depths near the bank. Traps were deployed at least 10 feet apart. Each trap included an identification number. The time of deployment, site geographic coordinates, substrate type, average trap depth, habitat classification, dissolved oxygen measurement (mg/L) and water temperature (°C) readings were noted on field sheets (Appendix A). We left traps in position overnight for a time period of no more than 12 hours, per USFWS guidelines.

Musk turtles are able to remain submerged for long periods of time due to their ability to obtain oxygen from the water through their vascular tissue (Gatten 1984; Bailey and Bailey

2002). This respiratory feature allows them to survive the forced submersion incurred during the trapping. However, since the turtles obtain oxygen from the water, the dissolved oxygen (DO) level of the water is crucial for their survival. DO and water temperature readings were taken before trap deployment at each site. In order for trapping to take place, a minimum DO level of 6.0 mg/L was required, as well as a water temperature of less than 31° C (88° F). Traps were deployed during nighttime hours to facilitate these requirements. Water temperature was also a determinant of the length of the trapping seasons, which typically occurred from April through mid-June, and from September through late October, times in the year when *S. depressus* is expected to be active, but its survival would not be compromised due to the DO level.

We retrieved traps shortly after daylight, within 12 hours of deployment. The contents of the trap were noted and returned to the shoreline. We measured (CL in mm), noted the sex of, and photographed (carapace and plastron) any *S. depressus* caught. Other species of turtles caught during the trapping were the river cooter (*Pseudemys concinna*), spiny softshell (*Apalone spinifera*), pond slider (*Trachemys scripta*) and the common musk turtle (*Sternotherus odoratus*).

A total of 155 sites were trapped during three trapping seasons from April 2011 to June 2012 (Figure 3.8). Trap sites were randomly selected from among the three habitat designations. We did not set traps in “Bluff” segments because of logistical challenges associated with the bluff features and the absence of appropriate turtle habitat at trapping depths. Throughout the three trapping seasons (spring and fall 2011, spring 2012) we set 55 trap sites in “Good” habitat, 53 in “Moderate” habitat, and 47 in “Poor” habitat (Figure 3.9).

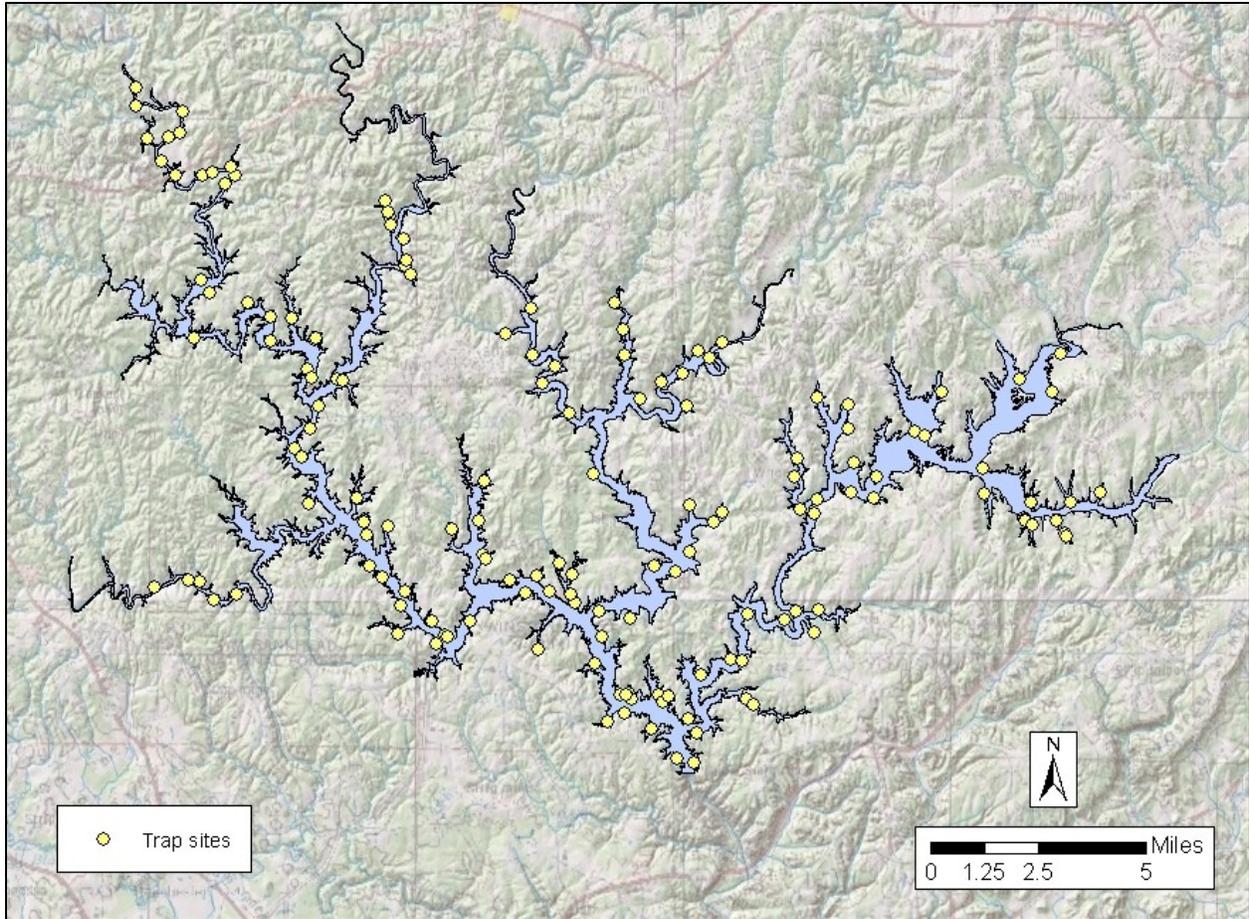


Figure 3.8 Locations of trap sites on the shoreline of Smith Lake

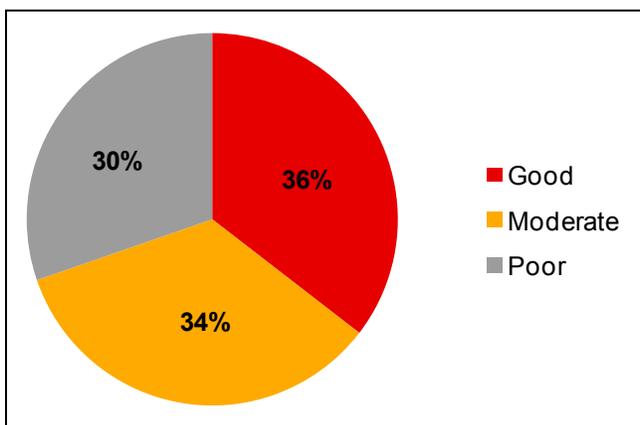


Figure 3.9 Percentage of traps placed in each habitat type

After the spring 2012 trapping season, I compiled and organized the trapping data from all three trappings seasons (spring 2011, fall 2011, spring 2012) from various existing files and field sheets into a spreadsheet format for use in SPSS. I also used the geographic data recorded on the field sheets to create GIS shapefiles of trap sites.

CHAPTER 4

RESULTS

Descriptive Statistics

Of the approximately 1,100 km of shoreline surveyed on Smith Lake, 224 km (20 percent) were designated as “Good” habitat, 296 km (27 percent) were designated as “Moderate” habitat, and 530 km (48 percent) were designated as “Poor” habitat. Shoreline designated as “Bluff” habitat totaled 50 km (5 percent). (Figure 4.1)

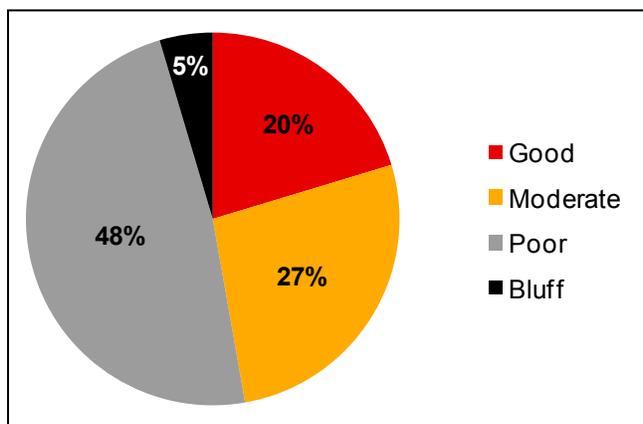


Figure 4.1 A breakdown of the habitat types comprising Smith Lake shorelines

Of the 155 trap locations, 25 (16.1 percent) successfully captured one or more *S. depressus* (Figure 4.2). Examination of the habitat type of these 25 sites shows that 14 (56 percent) were located in “Good” habitat, nine (36 percent) were located in “Moderate” habitat, and two (8 percent) were located in “Poor” habitat (Figure 4.3). Thus, 92 percent of trap

sites that were positive for the presence of *S. depressus* were located in “Good” or “Moderate” habitat. Of the two instances in which turtles were trapped in “Poor” habitat, those trap sites were located within 150–350 feet of “Good” or “Moderate” habitat segments, either adjacent to or across a narrow channel from them.

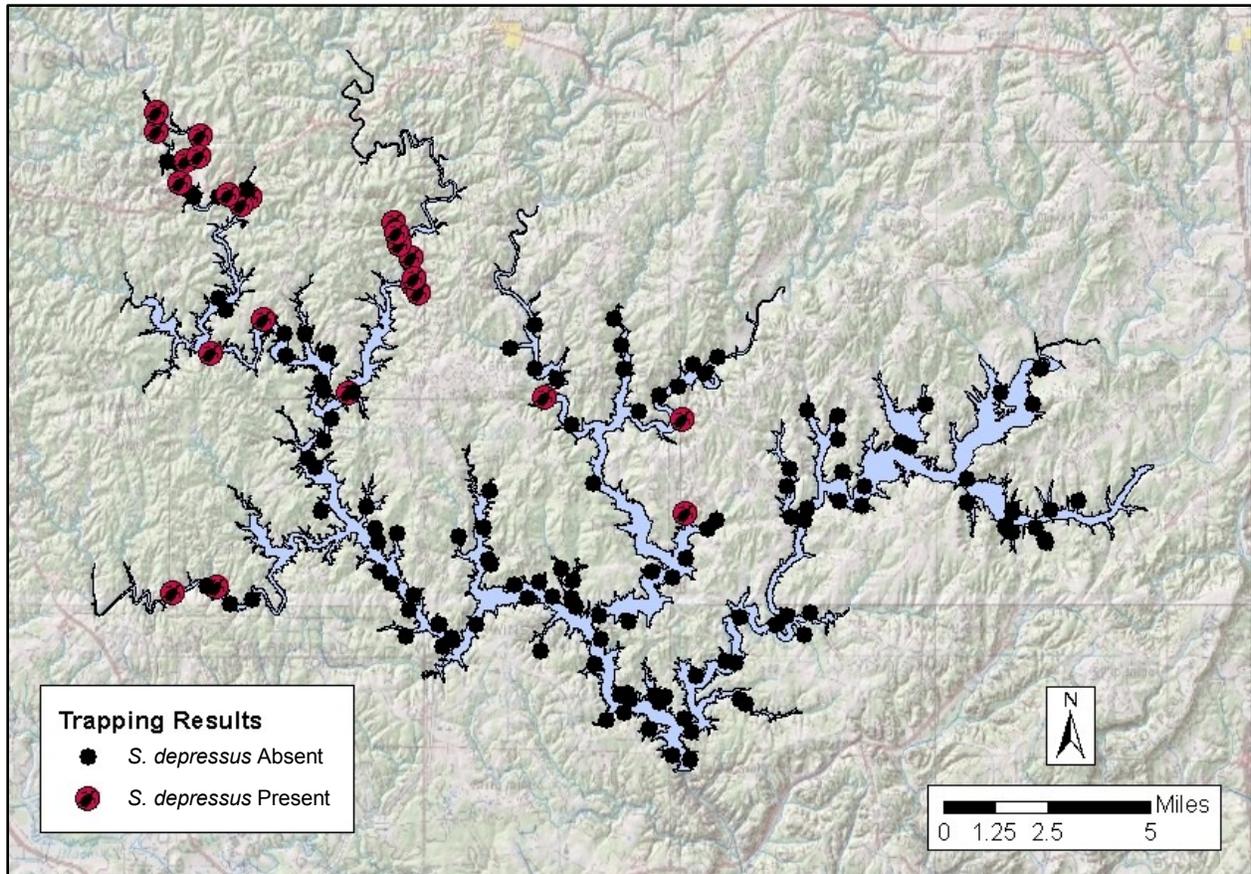


Figure 4.2 Results of *S. depressus* trap sites

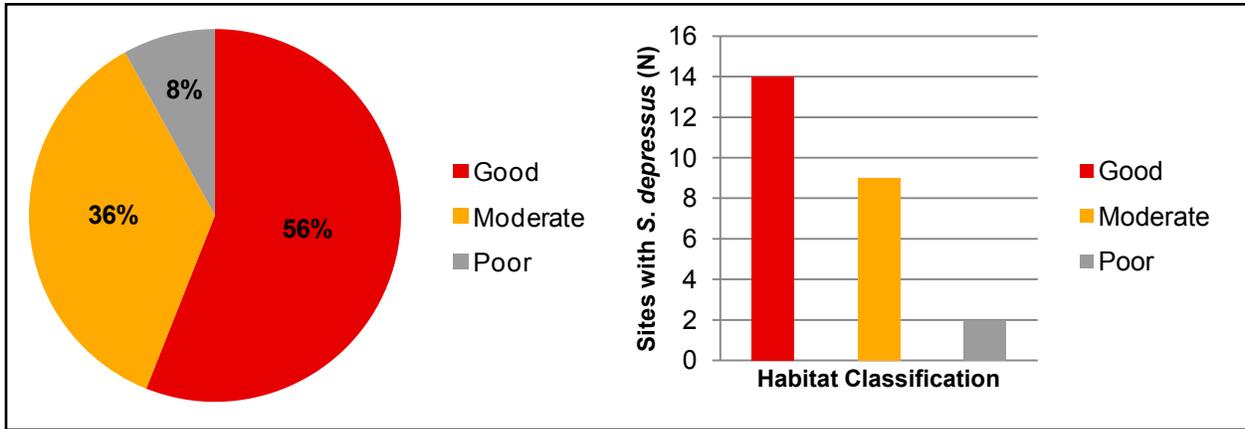


Figure 4.3 Habitat classification of sites where *S. depressus* was successfully trapped, by percentage (left) and number (right)

The capture rates tell the percentage of trap sites that caught *S. depressus*, and can be broken down by habitat type (Table 4.1). “Good” sites had a capture rate of 25.5 percent, “Moderate” sites had a capture rate of 17 percent, and “Poor” sites had a capture rate of 4.3 percent. Trapping efficiency ranged from 0.004 *S. depressus* per trap night at the “Poor” sites to 0.054 *S. depressus* per trap night at the “Good” sites.

Table 4.1 Capture rates for each habitat type

Habitat	Sites with <i>S. depressus</i>	Trap Sites	Capture Rate (%)
<i>Good</i>	14	55	25.5
<i>Moderate</i>	9	53	17.0
<i>Poor</i>	2	47	4.3
<i>All</i>	25	155	16.1

Statistical Tests

I performed a chi-square test for independence using data that indicate the presence or absence of *S. depressus* and the shoreline habitat classification of the trap site (Table 4.2). This

test compares the observed versus expected values for each cell. The null hypothesis (H_0) states that the presence or absence of *S. depressus* and the habitat classification of the trap site are independent variables and have no association. The results of the chi-square test indicate an association between *S. depressus* capture status and site habitat classification ($\chi^2 = 8.463$, $N = 155$, $p = 0.015$). The contingency table (Table 4.3) gives the observed counts and expected counts for all combinations of habitat types and trapping results, along with row and column percentages.

Table 4.2 Results of chi-square test of independence

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.463 ^a	2	.015
Likelihood Ratio	9.725	2	.008
N of Valid Cases	155		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.58.

Table 4.3 Chi-square contingency table with percentages

Habitat Type * *S. depressus* Results Crosstabulation

			<i>S. depressus</i> Results		Total
			Absent	Present	
Habitat Type	Good	Count	41	14	55
		Expected Count	46.1	8.9	55.0
		% within Habitat Type	74.5%	25.5%	100.0%
		% within <i>S. depressus</i> Results	31.5%	56.0%	35.5%
		% of Total	26.5%	9.0%	35.5%
	Moderate	Count	44	9	53
		Expected Count	44.5	8.5	53.0
		% within Habitat Type	83.0%	17.0%	100.0%
		% within <i>S. depressus</i> Results	33.8%	36.0%	34.2%
		% of Total	28.4%	5.8%	34.2%
	Poor	Count	45	2	47
		Expected Count	39.4	7.6	47.0
		% within Habitat Type	95.7%	4.3%	100.0%
		% within <i>S. depressus</i> Results	34.6%	8.0%	30.3%
		% of Total	29.0%	1.3%	30.3%
Total	Count	130	25	155	
	Expected Count	130.0	25.0	155.0	
	% within Habitat Type	83.9%	16.1%	100.0%	
	% within <i>S. depressus</i> Results	100.0%	100.0%	100.0%	
	% of Total	83.9%	16.1%	100.0%	

Therefore, *S. depressus* does not appear to be evenly distributed along the Smith Lake shoreline. *Sternotherus depressus* is more often trapped in “Good” and “Moderate” habitats than in “Poor” habitat. Thus, I reject the null hypothesis (H_0) of no association between variables.

CHAPTER 5

DISCUSSION

Geospatial Assessment

Visual assessment of the projected trapping data indicates that *S. depressus* is more likely to be found in the narrower creeks and tributaries rather than on the main channels. The clustering of sites where *S. depressus* was captured appears to reflect the results of previous studies (Rogers and Marion 2004). Seventeen of the 25 sites where *S. depressus* was found were located in either the upper reaches of the Sipsey Fork or in Brushy Creek, locations where populations of *S. depressus* have been found in prior studies. Other than at these two sites, captures took place at relatively isolated sites (i.e., in different creeks or separated by a significant distance). This could be an indication of population decline or collapse at isolated sites. Also, no *S. depressus* was captured in the entire Ryan Creek portion of Smith Lake, even though it was found at two sites in Ryan Creek in Bailey and Bailey's 2003 study.

This could be caused by a lack of immigration into Ryan Creek from other sites, as the sites at which we most commonly captured *S. depressus* were located on the opposite end of the lake, a much farther distance than *S. depressus* individuals have been known to travel. Also, much of the land surrounding the Ryan Creek portion of Smith Lake is used for agricultural purposes (Alabama Power 2000). This could cause Ryan Creek to receive agricultural runoff and siltation, factors among those listed as contributing to the elimination of portions of *S. depressus* habitat. In contrast, the Sipsey Fork, Brushy Creek and Clear Creek portions of the

lake (where we found *S. depressus* in this study) drain heavily forested areas and parts of the Bankhead National Forest (Alabama Power 2000), landscapes typically associated with better water quality than agricultural drainages. Also, Ryan Creek has a higher percentage (approximately 67 percent) of shoreline that is classified as “Poor” or “Bluff” than either Rock Creek (approximately 41 percent) or Brushy Creek (approximately 46 percent). Thus, the availability of desirable *S. depressus* habitat is not as abundant in Ryan Creek as in other parts of Smith Lake. Additional trapping efforts may yet yield *S. depressus* in Ryan Creek. As this study was not a population density study, conclusions cannot be made regarding quantitative population growth or decline.

Alternative Shoreline Development

Shoreline development at Smith Lake accelerated in the mid-1990s, as the number of homes on the lake more than doubled from 1995–2007 (Feldman 2008). APC has identified enhancement measures that will be required for all permitted activities that will alter the shoreline of habitat likely to house *S. depressus* (below the 510-foot full pool level) (Alabama Power 2012). These guidelines aim to minimize or avoid impacts to *S. depressus* and its habitat incurred by the shoreline permitting program (e.g., construction activity).

APC has developed an Enhanced Natural Stabilization method that gives details on installing native rock material, along with crushed stone, sand, plants and woody debris, to create an erosion barrier that is also turtle friendly. The use of these materials on the shoreline can be configured so that additional *S. depressus* habitat is created or sustained. This suggested method of erosion control gives the turtles suitable cover and crevices and provides access to nesting areas while still providing bank erosion control. APC has constructed a demonstration site for

contractors to observe and learn the techniques for implementing these shoreline stabilization guidelines. APC will also offer annual training sessions at this site to demonstrate best practices.

In addition to the shoreline stabilization guidelines, APC has implemented restrictions on the time of construction to better protect *S. depressus* in the vicinity. Based on historical data (Dodd 2008; Mount 1981; Ernst *et al.* 1994; Dodd *et al.* 1988) as well as the 2011–2012 sampling events, *S. depressus* appears to be relatively inactive from November through April. These months also coincide with winter pool, during which water levels are typically dropped by 14 feet from full pool. Therefore, shoreline construction during this time should have a reduced effect on *S. depressus* versus construction during full pool. This timeframe also prevents construction during *S. depressus* nesting periods, which typically occur in the summer months (Close 1982).

Shoreline Management Implications

Practices that have the potential to impact *S. depressus* habitat include physical alteration of habitat (e.g., seawall construction, riprap placement), destruction of habitat (e.g., dredging), blocking access to nesting sites (e.g., seawall construction), and siltation from land-disturbing activities (Alabama Power 2012). As part of the shoreline development plan, the effects of construction or other shoreline-altering activities must be known and considered during the permitting process. Activities requiring a permit were evaluated for their effects on *S. depressus* habitat and individuals, with regards to the habitat type of the proposed sites. Some activities are unlikely to affect either *S. depressus* individuals or their habitat (e.g., installation of floating boat houses or piers that anchor to the shoreline above the 510-foot full-pool level). Activities that would alter the shoreline are subject to restrictions regarding size and extent, timing of

construction, and the use of Enhanced Natural Stabilization (ENS) methods that use slopes and materials favorable to *S. depressus* adults for foraging and protective cover (Alabama Power 2012).

Recommendations

Various conservation and management recommendations have been made for different turtle populations worldwide (Bodie 2001; Klemens 2000; Heppell 1998; Benz and Collins 1999). Populations face different threats relative to cultural differences of nearby human populations, the degree of interest by regional and national governments, and habitat limitations. To combat these threats, various conservation strategies have been proposed and attempted during the past 50–60 years (Moll and Moll 2004; Bodie 2001; Alho 1985; Buhlmann 1995; Turtle Conservation Fund 2002; Klemens 2000; Ferraro and Gjertsen 2009). Conservation strategies have one of two approaches: in-situ and ex-situ, and can be used in conjunction with one another (Moll and Moll 2004). In-situ strategies involve working with the existing species in their natural habitats, such as designating areas as nature preserves, targeting pollution and siltation, and other methods. Ex-situ strategies typically require removal of individuals or their nests and involve procedures such as captive breeding and headstarting. Many turtle conservation strategies have been experimented with, especially in areas with intense harvesting pressure, such as Southeast Asia and South America (Klemens 2000; Moll and Moll 2004; Ferraro and Gjertsen 2009; Risien and Tilt 2008). However, the laws and provisions are only as good as their enforcement (Moll and Moll 2004). Regulations such as the addition of turtle-excluder devices on commercial shrimping nets help to reduce incidental by-catch of sea turtles (Moll and Moll 2004). Some nations only allow licensed parties to harvest at-risk turtle species,

with the licensing fees directed toward conservation efforts. Other conservation strategies to address threats include: identification and regulation of trot lines, bans on 0.22-caliber rifles in boats, elimination or regulation of the turtle trade market, exploration of the feasibility of farming turtles for human use instead of collecting wild turtles, and promotion for the awareness of the issues facing turtle populations today (Klemens 2000). However, not all conservation strategies prove to be effective. For example, some governments have placed size limits on the turtles that can be legally captured or removed from the wild. But as with many long-lived species, the removal of mature adults, especially females, does much more harm to the viability of the population than the loss of juveniles, which have a naturally high mortality rate (Moll and Moll 2004; Heppell *et al.* 1996).

The *S. depressus* population has been affected by removal by collectors, with reports of several hundred individuals being taken from various streams in the watershed (Reece 1987; Dodd *et al.* 1988). However, the enactment of the ESA and the passage of a State law prohibiting the collection of *S. depressus* serve to curtail the practice. The conservation strategies listed in the Flattened Musk Turtle Recovery Plan (USFWS 1990) are primarily in-situ in nature, and include improving habitat quality (with attention to abandoned mines), monitoring the population status, reduction of ongoing adverse actions, minimizing isolation of *S. depressus* populations, reduction of incidence of disease, if necessary, and reduction of adverse genetic exchange with *S. minor* above Bankhead Dam. Some of these actions were begun prior to FY 1995, while some have yet to be initiated, and most actions have estimated completion dates of FY 2020–2030 (Table 5.1). Because of the low reproductive rate of *S. depressus*, even under favorable circumstances the time required to evaluate the success of the recovery efforts exceeds 30 years (USFWS 1990). The reproductive characteristics of *S. depressus*—their age at sexual

maturity and low fecundity—do not encourage captive breeding or hatcheries as viable conservation techniques (USFWS 1990; Bailey and Bailey 2002; Lovich 2010).

Table 5.1 USFWS Flattened Musk Turtle Recovery Plan action status.

Action Description	Action Status	Est. Initiation Date	Est. Completion Date
Develop habitat restoration plan	Partially complete	Prior to FY 1995	FY 2010
Implement habitat restoration plan	Ongoing current	Prior to FY 1995	FY 2020
Develop study plan	Partially complete	Prior to FY 1995	FY 2018
Conduct studies	Ongoing current	FY 2011	FY 2020
Reduce ongoing adverse actions	Ongoing current	Prior to FY 1995	FY 2030
Minimize isolation	Not started	FY 2021	FY 2030
Decrease incidence of disease	Not started	FY 2021	FY 2030
Reduce adverse genetic exchange above Bankhead Dam	Not started	FY 2021	FY 2030

Challenges

One approach often considered in T&E management is direct population manipulation. This occurs when animals are placed into habitats to revive or re-establish a population. These added animals can originate from captive breeding programs, wild populations needing to be relocated, or from other, more stable populations located elsewhere. Population manipulation has been beneficial for a number of bird and mammal species (Griffith *et al.* 1989), but its affect on reptiles and amphibians has had much less success (Dodd and Seigel 1991). Dodd and Seigel (1991) reviewed 26 previously conducted population manipulation studies and reports for reptile

and amphibian species, and found that five were successful (i.e., resulted in a self-sustaining, stable population), six were unsuccessful, and the remaining 15 could not be classified. Of these five successful projects, four involved crocodylian species. Dodd and Seigel (1991) caution against labeling a population manipulation project as successful based on a limited monitoring period relative to the species' life history. A vital element in a successful population manipulation project is the attention to the issues that caused the population to decline in the first place. Simply inserting new individuals will not reverse the root cause. Long-term monitoring of turtle populations is difficult because of the relatively long lifespan of turtles, therefore the impact of such projects on the viability of individual populations is challenging to determine (Browne and Hecnar 2007; Congdon *et al.* 1993, Congdon *et al.* 1994; Moll and Moll 2004). Other challenges to successful population manipulation projects include lack of attention to biological, demographic and biophysical constraints; lack of life history information; population genetics; and disease transmission (Dodd and Seigel 1991). Tuberville (2008) states that minimizing adult mortality is a better approach to conservation than supplementing a population with only hatchlings and juveniles. It is unlikely that the flattened musk turtle population in Smith Lake would greatly benefit from a captive breeding or reintroduction program because of their long lives, delayed sexual maturity and low fecundity. Unless carefully monitored, the release of individuals raised or bred in captivity invites the possibility of introducing disease into the wild population, which could prove catastrophic.

Nesting Behavior

Having suitable nesting habitat nearby is an important requirement for aquatic turtles, which venture to shore to lay their eggs (Marchand and Litvaitis 2004; Rizkalla and Swihart

2006; Mitchell and Klemens 2000). Often, these areas desirable for nesting purposes are not contiguous to the ideal adult turtle habitat (Moll and Moll 2004). Thus, areas near “Poor” shoreline could be good nesting habitat, while areas considered “Good” adult habitat could be marginal for nesting. In order to properly protect *S. depressus* habitat, the habitat requirements of all life stages must be considered, particularly nesting habitat. Conservation of nesting habitat is important to the viability of a turtle population, as adults appear to be less flexible in their nesting and reproductive habits than with other habits, such as foraging (Moll and Moll 2004). *Sternotherus depressus* females prefer nesting sites that have loose or sandy substrate within 100 feet of the shoreline (USFWS 2009). However, the description of ideal nesting habitat is based on very few observations. One *S. depressus* nest was discovered by Dodd *et al.* (1988) on a high sandy bank on the shore of the Sipsey Fork. The nest, which consisted of two eggs, was shallow and was located 6.5 m from the water under slight vegetation, where it received afternoon sunlight. Bailey and Bailey (2002) conducted a tracking study in Blackwater Creek (a tributary of the Mulberry Fork) to observe the nesting behavior of *S. depressus* females. Two of the eight female *S. depressus* they tracked were observed on nesting forays—one was located in a privet hedge 115 m from the nearest point of the stream, and the other on the highest point of a small island under live vegetation 5 m from the stream. Before the Bailey and Bailey (2002) study *S. depressus* had not been found more than 10 m from the shore. Because of the limited amount of data regarding *S. depressus* nesting practices, especially regarding lentic populations, management decisions regarding conservation of nesting habitat are difficult to make. Future tracking studies could help identify the preferred nesting habitat of *S. depressus*, which could then be incorporated into management plans such as the habitat classification for the shoreline of Smith Lake.

Future Study

This study examined *S. depressus* distribution in Smith Lake based on presence-absence data in order to evaluate a habitat classification system. However, based on the nature of the data, no evaluation could be made regarding the density of the *S. depressus* population.

A study involving tracking *S. depressus* movement would provide valuable information about their range. This would be particularly helpful when evaluating the edges or overlapping segments of habitat types. For instance, of the two individuals trapped in “Poor” habitat, both were within 150–350 feet of “Good” or “Moderate” habitat segments, and were located among the “clusters” of trapped *S. depressus* in better habitat segments. Thus, if the movement range of *S. depressus* was known, it could be deduced whether or not the turtles found in “Poor” habitat could reside in or originate from the adjacent habitat segments. A tracking study could also help in understanding the little-known nesting habits of *S. depressus*. Knowledge about how far females are willing to travel to find nesting sites, and whether they return to the same site throughout the years could be valuable, especially in shoreline management and conservation planning.

Factors to Encourage Survival

The use of ENS methods can increase potential *S. depressus* habitat by incorporating slope and material preferred by *S. depressus* into shoreline projects. If these methods are required for certain construction activity (below the 510-foot full-pool level) and are used by APC to repair erosion sites along its shoreline property, the amount of favorable *S. depressus* habitat should increase.

CHAPTER 6

CONCLUSION

Based on the ground-truth survey, it appears that the shoreline classification system can accurately predict the location of *Sternotherus depressus*. The knowledge of where the favorable *S. depressus* habitat is located is a valuable resource in shoreline management. The shoreline segments designated “Good” and “Moderate” can be projected in the form of a GIS shapefile and designated as “Sensitive Resources”. Thus, when Smith Lake property owners apply for construction permits, shoreline managers can reference the Sensitive Resources shapefile to determine if the property overlaps any sensitive areas, including T&E species habitat as well as historic or cultural sites, or wetland areas, among others. Certain activities could be prohibited or significantly altered to avoid or minimize the impact to the sensitive area. In areas known to have a relatively high number of *S. depressus* based on this study, development guidelines could be required regardless of the habitat classification in order to protect individual turtles that might use multiple habitat segments on a stretch of shoreline. Without knowledge of the location of likely *S. depressus* habitat, each permit would have to be individually trapped and considered, requiring much time and manpower.

In addition to creating a resource for the shoreline management of Smith Lake, this study contributes to the accumulation of data regarding *S. depressus* distribution in Smith Lake, a less-than-ideal environment for the primarily stream-dwelling turtle species (Dodd 1990; Reese and

Welsh 1998). The availability of data such as this is valuable for current management practices as well as future studies.

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