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# *Sternotherus minor* – Loggerhead Musk Turtle

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**Summary. – The loggerhead musk turtle, *Sternotherus minor*, is a small, highly aquatic species that occupies a variety of habitats throughout its range in the southeastern United States. It is a conspicuous and common freshwater turtle in the spring runs, streams, and rivers of northern and western Florida. As a result, it has been subject to some pressure from commercial collectors for sale in the pet trade. Nevertheless, these turtles are prolific and populations appear to be stable in certain Florida river systems. In fact, loggerhead musk turtles reach among the highest densities known for any species of turtle. Under ideal habitat conditions at a head spring in northwest Florida, loggerhead musk turtle density was reported to be 2857 per hectare. *Sternotherus minor* can be distinguished from other musk and mud turtles by the presence of a weak single plastral hinge, dark markings against a light background on the head, two barbels on the chin, three keels on a brown carapace, and overlapping carapacial scutes. In northern Florida, mating has been observed in the field in September, November, March, and April. Female receptivity to mating peaks from April to May. Females in north central Florida may lay 2 or 3 clutches of eggs each year, with a maximum of 5 clutches. These are laid between September and July, sometimes at communal nest sites. Typical clutch size ranges from 1–5 eggs (averaging 3), with the number of eggs positively correlated with female carapace length. Incubation takes 61–119 days, with slower embryonic development resulting from cool weather. Sex is determined by mean incubation temperature; only females result from temperatures of 30ºC or higher, and mostly females are produced at temperatures 27–30ºC and 24ºC or less. Mostly males are produced at intermediate temperatures of 25–26ºC. Given their ability to thrive and reproduce in suitable freshwater habitat, loggerhead musk turtles are not likely to become seriously threatened unless the water quality in the rivers and streams deteriorates.**

**Conservation Status. – FNAI Global - G5 (Demonstrably Secure), State - S4 (Apparently Secure); ESA Federal - Not Listed; State - Not Listed; CITES - Not Listed; IUCN Red List - Not Listed (LC-Least Concern).**

*Species Recognition.* — The loggerhead musk turtle, *Sternotherus minor*, is a small species (up to 14.5 cm carapace length; Enge and Foster, 1986; Camp, 1986) with a highly domed brown shell with black flecks or streaks (Fig. 13-1). The brown head can be quite large, with a pointed snout and obvious, dark dots and/or blotches (Figs. 13-1, 13-2, 13-3). This species lacks prominent facial stripes. The skin is brown to gray with dark brown or black markings (Iverson, 1977b). The underside of the neck and limbs has a pink or reddish tinge, blending to brownish orange on the lower jaw and cream brown on the upper jaw (Tinkle, 1958a). Two barbels are present on the chin (Iverson, 1977b). The plastron is unmarked; pinkish to dull orange in color in juveniles, fading to a duller shade of orange, cream, or yellow in adults (Fig. 13-4), but may be stained a darker color. The carapace has overlapping scutes. The reduced plastron (Fig. 13-4) has 11 plastral scutes, including a single gular scute. There is a single, indistinct plastral hinge between the abdominal and pectoral scutes. The pectoral scutes are square in shape. The first vertebral scute does not contact the second marginal, and the tenth and eleventh marginal scutes are raised above the line formed by more anterior marginals (Iverson, 1977b).

Hatchlings have a median keel and two obvious lateral keels on a carapace that is colored as those of adults. The three keels become less apparent with increasing size and age (Tinkle, 1958a). The plastron of new hatchlings is bright pink (Fig. 13-5).

The adult head is adapted to consuming gastropods, with sizeable musculature and wide dentary surfaces for crushing shells. Adults have a pugnacious disposition and bite readily (Carr, 1952, among others). Like other musk turtles, a gland containing a malodorous yellowish secretion is located at the base of each limb near the bridge (Ehrenfeld and Ehrenfeld, 1973).

*Sternotherus minor* can be distinguished from other musk and mud turtles by the presence of a single plastral hinge (vs. two hinges in most mud turtles, genus *Kinosternon*), dark markings against a light background on the head (vs. prominent facial stripes), two barbels on the chin (vs. on the neck or on the neck and chin), three keels (vs. one keel), a basically brown carapace (vs. a basically black shell), and overlapping carapacial scutes (vs. carapacial scutes not

**Figure 13-1.** Juvenile loggerhead musk turtle, *Sternotherus minor*, from Marion Co., Florida. Photo by Alice Monroe.

overlapping those more posterior) (Iverson 1977b: Conant and Collins, 1998).

*Taxonomic History*. — The loggerhead musk turtle was originally described by Agassiz (1857) as *Goniochelys minor* based on a series of specimens from the neighborhood of Mobile, Alabama; Columbus, Georgia; and New Orleans, Louisiana. The type-locality was restricted to Columbus, Georgia by Schmidt (1953). Strauch (1862) assigned this turtle to the genus *Aromochelys*, but it was reassigned to the genus *Sternotherus* by Stejneger (1923). Carr (1952) referred to the loggerhead musk turtle as *Sternotherus carinatus minor*. However, Tinkle (1958a) resurrected the name *Sternotherus minor* in his review of the genus.

Turtles of the genus *Sternotherus* are members of the family Kinosternidae, subfamily Kinosterninae. "*Sternotherus*" is derived from the Greek "*sternon*" meaning "chest" and "*thairos*" meaning "hinge," in reference to the hinged plastron. The plastron opens anteriorly to permit the large head size, the consumption of large gastropods, and the defensive stance of retracting the head while keeping the jaws agape (Bramble et al., 1984). The species name *minor* refers to its smaller size when compared with *S. carinatus* (Agassiz, 1857).

There are two subspecies of *Sternotherus minor*: *Sternotherus m. minor*, the loggerhead musk turtle, and *Sternotherus m. peltifer*, the stripe-necked musk turtle (Smith and Glass, 1947). Intergradation between the subspecies occurs in Alabama and west Florida (Mount, 1975; Iverson, 1977a). Because of its similarity and complementary distribution in northern Alabama,

**Figure 13-2.** Head of juvenile loggerhead musk turtle, *Sternotherus minor*, from Liberty Co., Florida. Photo by Dick Bartlett.

**Figure 13-3.** Head of adult loggerhead musk turtle, *Sternotherus minor*, from Marion Co., Florida. Photo by Tim Walsh.

**Figure 13-4.** Plastral view of adult female **(left)** and adult male **(right)** loggerhead musk turtles, *Sternotherus minor*, from Marion Co., Florida. Photo by Tim Walsh.

*Sternotherus depressus*, the flattened musk turtle, was considered a subspecies of *S. minor* by some authors (e.g., Tinkle and Webb, 1955; Mount, 1975); however, it is now regarded as a distinct species (Seidel and Lucchino, 1981; Seidel et al., 1986; Ernst et al., 1988; Walker et al., 1995; Iverson, 1998).

Preliminary work on geographic variation in DNA sequences has been done (Walker et al., 1995). However, additional studies with more complete geographic sampling are needed in order to compare with the patterns of morphological variation on which the subspecies are based.

*Sternotherus minor* is known to hybridize with *S. odoratus* in captivity (Folkerts, 1967), and suspected hybrids have been found in the field in the Rainbow River in Florida (Iverson, unpubl. data). *Sternotherus minor* is suspected of hybridizing with *S. depressus* in Alabama (Estridge, 1970).

**Figure 13-5.** Plastral view of hatchling loggerhead musk turtle, *Sternotherus minor*, from Gilchrist Co., Florida. Photo by John Iverson.

## DISTRIBUTION

*Geographic Distribution.* — The loggerhead musk turtle is found in the southeastern United States (Iverson, 1977b, 1992) from southwestern Virginia (Mitchell, 1994), eastern Tennessee (Scott et al., 2000), and western North Carolina (Palmer and Braswell, 1995), south through eastern Georgia (Williamson and Moulis, 1994) to central Florida (Iverson and Etchberger, 1989), and west through Alabama (Mount, 1975) to the Pearl River system of south-central Mississippi and Washington Parish, Louisiana (Dundee and Rossman, 1989).

The distribution of the loggerhead musk turtle in Florida includes at least 29 counties from as far south as the central peninsula close to Orlando (Seminole County) in the St. John's drainage system and further west in the Withlacoochee River system in Sumter County (Stevenson and Crowe, 1992). It is found across the northern one-third of the peninsula and west throughout the panhandle (Iverson and Etchberger, 1989; Fig. 13-6). The population in the Withlacoochee drainage in Marion, Citrus, and Sumter counties appears to have been introduced to that river system in the late 1950s (Meylan et al., 1992; Iverson and Paull, 2004; Huestis and Meylan, 2004). A single record for Highlands County (Meshaka and Gallo, 1990) probably represents an introduction.

*Ecological Distribution.* — The loggerhead musk turtle is a highly aquatic species that inhabits spring runs, creeks, rivers, oxbows, swamps, and sinkhole ponds (review in Ernst et al., 1994). It favors areas around submerged fallen trees and snags where sandy or rocky substrate is present (Jackson, 1988, among others). In northern and central Florida, it is most abundant in clear spring runs (Marchand, 1942; Carr, 1952; Berry, 1975; Iverson, 1977a; Cox and Marion, 1978, 1979; Meylan et al., 1992; Onorato, 1996; Guntermann, 1998).

## HABITAT RELATIONS

*Activity.* — Loggerhead musk turtles are not strong swimmers and are more often seen walking along the bottom rather than swimming (Ditmars, 1936). Carr (1952) observed that their sometimes furious swimming motions only produced slow progress. In clear artesian springs and spring runs in Florida, loggerhead musk turtles are often seen walking on the river bottom or swimming in the aquatic vegetation at depths of 2 to 4 m (JBI and RTZ, *pers. obs.*). Hensley (1994) observed an adult male *S. minor* at 12.5 m depth in a spring-fed sinkhole at Manatee Springs State Park, Florida, feeding on a crayfish; after several seconds, the turtle retreated beneath a log 13 m deep. This observation suggests that *S. minor* can forage at considerable depths when those habitats are available. Based on trapping evidence (e.g.,

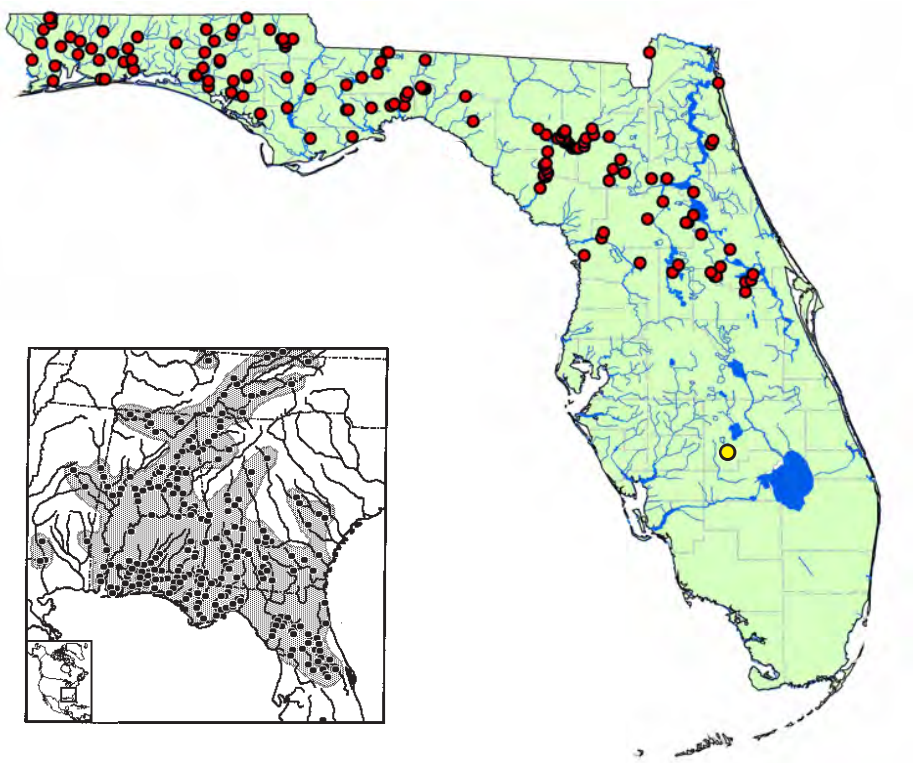

**Figure 13-6.** Known distribution records for the loggerhead musk turtle, *Sternotherus minor*, in Florida. Inset: distribution records from entire range of *S. minor* (adapted from Iverson, 1992; distribution in inset map not current for Florida as presented here). This species is thought to be introduced to the Withlacoochee River (south) system (Meylan et al., 1992; Huestis and Meylan, 2004). The southeastern-most record in Highlands Co. (yellow dot) probably represents an escaped individual.

Tinkle, 1958b), loggerhead musk turtles feed mostly at dawn and dusk; however, they have also been observed foraging throughout the daytime, as well as late after dark (P. Meylan and JBI, *pers. obs.*).

Hatchling, juvenile, and adult loggerhead musk turtles often seek shelter in submerged crevices or root-snags (Jackson, 1988). They also occupy crayfish burrows and submerged hollow logs as retreats (JBI and P. Meylan, *pers. obs.*). During periods of cooler weather they remain hidden in the safety of these retreats (RTZ, *pers. obs.*).

Loggerhead musk turtles spend nearly all of their time in water; terrestrial records are very rare (JBI, unpubl. data). They have the ability to remain submerged indefinitely in well-oxygenated water (Belkin, 1968). Ditmars (1936) kept several in a deep aquarium with no means of leaving the water. The turtles came to the surface occasionally, but spent most of the time crawling about the bottom of the tank. Similar to many other highly aquatic turtles, this species can obtain dissolved oxygen from water via the buccopharyngeal lining (Belkin, 1968; Gatten, 1984).

In the Florida springs which have constantly warm water temperatures, *S. minor* appears to be active year-round (Iverson, 1978; Cox and Marion, 1978; Jackson, 1988; Huestis and Meylan, 2004). Farther north, loggerhead musk turtles hibernate in cold weather, from December to February, probably in soft mud bottoms of waterways, in submerged rock crevices, and in the bank burrows of muskrats (Ernst et al., 1994).

Carr (1952) thought this species to be extremely fond of basking, and willing to undergo considerable exertion to climb to the highest branch, stump, or cypress knee available to bask. One male loggerhead musk turtle that he observed was balanced precariously for over an hour on the pointed tip of a cypress knee, almost two meters above the water, its every muscle quivering in the effort to remain in the sunlit area. Later authors (Tinkle, 1958b; Mount, 1975; Mitchell, 1994) have cited the climbing ability of *S. minor*, but suggested that the turtle's basking behavior is poorly developed. On several occasions RTZ saw loggerhead musk turtles basking in April or May on fallen tree snags or in shallow water (entire carapace exposed and dry) along the Apalachicola River. At least four captured specimens had leeches attached to the soft tissue of their leg sockets or on the fleshy portion of their plastron. Basking in *S. minor* may be a function of season or environmental temperature, but this behavior by the turtle may also be an attempt to rid itself of parasites (RTZ, *pers. obs.*).

## GROWTH AND REPRODUCTION

*Growth.* — There is considerable variation in growth rate across the range of *S. minor*. In west Florida, males reached 55 mm CL in 5.6 yrs (Cox et al., 1991), but in the Rainbow River in north Florida they attained that size in only 2 yrs (Onorato, 1996). Similarly, in west Florida females reached 80 mm CL in 8 yrs (Cox et al., 1991), but in north

Florida they attained that size in 4.5–5 (Onorato, 1996) or 5–6 yrs (Iverson, 1978).

*Dimorphism.* — Females grow significantly larger than males, averaging about 4 mm longer in CL (Iverson, 1977a). Carr (1952) noted that the long thickened tail of male loggerhead musk turtles is muscular and prehensile, with a terminal spine, and is often folded in two places in order to fit beneath the posterior edge of the carapace. Adult females have much shorter, slimmer tails than males. The anal opening is posterior to the carapacial margin in males (Ernst et al., 1994), and concavity of the plastron in males is slight or absent (Carr, 1952). A patch of tuberculate scales on the posterior surface of the crus and thigh of each hind leg is present in adult males (Iverson, 1977b). Both mature males and females (especially in *S. m. minor*) have noticeably enlarged (megacephalic) heads (Tinkle, 1958b). Nolan (1991) reported that the heads of adult females are noticeably paler than the darker heads of males.

*Maturation.* — Some geographic variation in sexual maturity exists, but in all cases males reach sexual maturity first and at smaller sizes than females. In northwest Florida, males mature at 55 mm CL (40 mm plastron length) in an average of 5.6 yrs (Cox et al., 1991), and those in central Florida mature at ca. 60 mm CL (ca. 45 mm PL) at 3 yrs (Etchberger and Stovall, 1990).

Females mature in northwest Florida at 70 mm CL (ca. 50 mm PL) after 8 yrs (Cox and Marion, 1978; Cox et al., 1991); those in north central Florida (Iverson, 1978) and in central Florida (Etchberger and Ehrhart, 1987) mature at ca. 80 mm CL (ca. 60 mm PL), but after 4.5–5.0 and 6 yrs, respectively.

*Male Sexual Cycle.* — In male *S. minor* from central Florida the testes enlarge from March through June as spermatogenesis begins, and maximum testis size occurs from August to October (Etchberger and Stovall, 1990). Testicular regression occurs from October to December, and by March the testes have shrunk to the size of those of juvenile males.

Agonistic behavior has been observed between males (Jackson, 1969). Captive adult males kept together in the presence of a female had to be separated due to aggressive behavior; however, the males were not aggressive toward males of other species (Nolan, 1991). Notching on the carapace edges of this species was abandoned as a marking method at Rainbow Run because in older males the margin of the shell becomes badly eroded (P. Meylan, *pers. comm.*; see also Jackson, 1965). At least part of this erosion may be due to aggressive encounters between adults (P. Meylan, *pers. comm.*).

*Female Sexual Cycle.* — Follicular enlargement begins in late August or September and continues through the following June (Iverson, 1978). Ovulation and oviposition occur from September or October through June or July (Iverson, 1978; Cox and Marion, 1978; Etchberger and Ehrhart, 1987). In Florida, females have no distinct period of ovarian regression during the year; however, there is a brief period of quiescence in late July and August (Iverson, 1978).

*Courtship and Mating.* — Courtship and mating of loggerhead musk turtles have been observed in the laboratory and in the field (Sachsse, 1977; Cox et al., 1980; Bels and LiBois, 1983; Nolan, 1991; Bels and Crama, 1994; Kirkpatrick, 1997). All wild matings were observed in early to mid-morning, and mated pairs remained completely submerged and partly concealed, and appeared to favor shaded areas (Cox et al., 1980). If disturbed, the pairs quickly uncoupled (Cox et al., 1980). As many as six males have been observed trying to mate with a single female at the same time (Ashton and Ashton, 1985). In northern Florida, mating has been observed in the field in September, November, March, and April (Cox, 1978; Cox et al., 1980). Female receptiveness to mating in northern Florida peaked from April to May; however, in captivity mating may occur virtually year-round (Nolan, 1991; Schilde, 2001). Loggerhead musk turtles reproduce readily in captivity (Rödel, 1989; Rogner 1996; Guntermann, 1998; Schilde, 2001).

No elaborate pre-copulatory behaviors have been observed on the part of the male (Cox et al., 1980; Bels and Libois, 1983; Nolan, 1991; Bels and Crama, 1994). The male rapidly approaches the female, sniffing at her cloaca and bridge. The female sometimes attempts to escape, with the male in close pursuit with his head extended toward her shell or head but without contact. Occasionally the male will face the female's head and swing his head side to side in front of her nose. In addition, he may bite at her shell or legs during sniffing or prior to mounting. The male then mounts her shell from behind and grasps the edge of her carapace with all four feet, curling his tail under hers to bring the cloacae into contact. The male then positions himself nearly perpendicular to the female's carapace, and mutual tail grasping precedes intromission. Occasionally the female may begin moving away during copulation, dragging the male upside down behind her, but still attached. In the laboratory, the entire sequence from initiation to completion took 2.67 hours (Cox et al., 1980). Coitus lasted 30 min in captives observed by Nolan (1991).

*Nesting.* — The only known regular terrestrial activity in this species occurs when females emerge for egg-laying (Mount, 1975; Cox and Marion, 1978; Gunterman, 1998). In northern Florida, gravid females apparently leave the water on nesting forays only in the early morning (0300 to 0900 hrs) following rain events (Cox and Marion, 1978). As a predator avoidance strategy, females may bury themselves while nesting, perhaps for several days (Cox and Marion, 1978). Eggs are sometimes laid singly or in groups in shallow holes or scrapes in the soil, especially at the base of trees or beside logs (Carr, 1952; Mount, 1975). However, most nests examined by Cox and Marion (1978) in northern Florida were located between 1 and 3.5 m above the water, and up to 40 m from the water's edge. They found the eggs at a depth of 8–15 cm below ground surface, thus supporting their speculation that females may bury themselves to nest (Cox and Marion 1978).

*Eggs.* — Eggs are elliptical, 21.2–33.0 mm long and 12.7–20.0 mm wide, and weigh between 2.0 and 6.7 g

(Cox and Marion, 1978; Iverson, 1978; Packard et al., 1984; Etchberger and Ehrhart, 1987; Nolan, 1991; Mitchell, 1994; Nagle et al., 1998). Egg size is generally not correlated with female body size (Iverson, 1978; Etchberger and Ehrhart, 1987); however, egg mass estimated from egg length and width was correlated with body size in one population in northwest Florida (Cox and Marion, 1978). Eggshells are about 0.32 mm thick (Packard et al., 1984), and the brittle eggshell is translucent pink when first laid, changing to white and opaque as the embryonic membranes develop (Iverson, 1978). Eggshells may crack late in incubation and extrude a viscous liquid without negative consequences to embryonic development (Iverson, 1978).

*Clutch Size and Reproductive Potential.* — Females in north central Florida may lay 2 or 3 clutches each year, with a maximum of 5 clutches, between September and July (Iverson, 1977c; Cox and Marion, 1978; Iverson, 1978; Etchberger and Ehrhart, 1987). Clutch size ranges from 1–5 eggs, averaging 3, with the number of eggs positively correlated with female carapacial length (Sachsse, 1977; Cox and Marion, 1978; Iverson, 1978; Etchberger and Ehrhart, 1987). Tinkle (1958b) estimated that female *S. m. minor* could produce an average of 6.3 eggs a year, but no precise localities were provided. In northwest Florida, Cox and Marion (1978) estimated annual reproductive potential to be 9.2; whereas Iverson (1978) estimated it to be 7.5 in north-central Florida, and Etchberger and Ehrhart (1987) estimated it to be 5.9 in central Florida. These data suggest a latitudinal increase in reproductive potential in this species.

*Incubation and Hatching.* — Incubation lasts for 61–119 days, with slower embryonic development resulting from chilling (Iverson, 1978; Ewert, 1985; Ewert and Nelson, 1991; Nolan, 1991). Sex determination in all kinosternids is also a function of incubation temperature (Ewert and Nelson, 1991). For *S. minor* only females result from temperatures of 30ºC or higher, and mostly females are produced at temperatures 27–30ºC and 24ºC or less (Ewert and Nelson, 1991). Mostly males are produced at intermediate temperatures (25–26ºC; Ewert and Nelson, 1991).

*Hatchlings.* — Hatchling CL is 22–30 mm; PL is 16–21 mm (Cox and Marion, 1978; Iverson, 1978). Neill (1948) found two loggerhead musk turtle eggs that a plow had unearthed on a hillside in August in Georgia. When opened, the eggs contained fully formed hatchling turtles with some yolk still attached. The hatchlings made only feeble movements, but were both fully able to void their musk glands, a defensive reaction that may reduce predation. Lehmann (1984) reported twin turtles from the same egg in captivity.

## POPULATION BIOLOGY

*Density and Biomass.* — Loggerhead musk turtles reach among the highest densities known for any species of turtle (Iverson, 1982). Marchand (1942) reported seeing 500 or more in a day of snorkeling in the Ichetucknee River in Columbia Co., in north Florida. Cox and Marion (1979) reported the density of loggerhead musk turtles under ideal conditions in a northwest Florida head spring to be 2857 per ha. Meylan et al. (1992) estimated 127 *S. m. minor* per ha in Rainbow Run, Marion County, Florida at a site where none were found in the 1940s (Marchand, 1942). In the Tallapoosa River in northern Alabama, Guyer and Herndon (1992) reported an estimated density for *S. m. peltifer* of 105 per ha.

*Population Structure.* — The sex ratio of both adults and juveniles fluctuates around 1:1 (Tinkle, 1958b; Cox, 1978; Guyer and Herndon, 1992; Meylan et al., 1992). In a population study at Rainbow Run, Onorato (1996) found that juveniles (5 yrs or less) represented more than 65% of the total population, although some turtles did live beyond 21 yrs. He postulated that this was a result of humans removing the largest individuals for pets or predation on adult turtles by alligators.

## INTERSPECIFIC INTERACTIONS

*Community Structure.* — Meylan et al. (1992) studied the turtle community in Rainbow Run, Marion Co., Florida, determined population size/structure for *S. minor* and *S. odoratus* (common musk turtle), and compared their results to a study of the same site by Marchand (1942). They found a major shift in abundance from *Pseudemys* spp. to *Sternotherus* spp. over the 50 year interval. *Sternotherus minor*, which was not observed during Marchand's study, made up 66% of the turtle composition in 1990; *S. odoratus* increased from 11.2% of the turtle community to 25% over the period.

*Diet and Feeding.* — The diet of wild juvenile *S. minor* includes insects, millipedes, spiders, earthworms, snails, crayfish, clams, fish, carrion, aquatic plants, and sometimes algae (Tinkle, 1958a; Folkerts, 1968; Ashton and Ashton, 1985). Like other musk turtles, they are primarily carnivorous and will swallow all kinds of bait (Carr, 1952). There is an ontogenetic shift in food preferences for *S. m. minor* from an insectivorous to molluscivorous diet (Tinkle, 1958b). Adults primarily consume snails and clams (Carr, 1952; Tinkle, 1958b; Folkerts, 1968; Palmer and Braswell, 1995), and develop powerful jaw musculature and expanded jaw surfaces to crush the shells of their prey.

This species may show cannibalistic tendencies. A captive juvenile *S. m. minor* killed and partially consumed 2 juvenile *Trachemys scripta*, a hatchling *S. m. minor* and a juvenile *S. m. peltifer* (Ernst et al., 1994).

*Competition.* — Carr (1952) noted that populations of this turtle were so large in some areas as to beg the question of how they all found enough to eat. Where concentrated populations of *S. minor* occurred, Carr (1952) found few or no specimens of *S. odoratus.*

*Sternotherus minor* is similar morphologically to other *Sternotherus*, especially *S. odoratus*, with which it

is sometimes microsympatric. Where they co-occur, there is considerable overlap in their use of available food resources, and some specimens of *S. minor* lack the usual enlarged head and jaws which is typical of adults elsewhere in Florida (Berry, 1975).

*Predation.* — Nest destruction can be caused by small mammals, crows, and reptiles (Ernst et al., 1994), although no direct observations have been made of egg predation. In captivity, northern scarlet snakes (*Cemophora coccinea copei*) ate the eggs of *S. minor* and other species of turtles readily and with frequency (RTZ, *pers. obs.*). The only confirmed non-human predator on adults is *Macrochelys temminckii*, the alligator snapping turtle (Pritchard, 1989). However, *S. minor* can detect and avoid alligator snapping turtles in their habitat by chemosensory means (Jackson, 1990). Ernst et al. (1994) also speculated that alligators consume these musk turtles. Britson and Gutzke (1993) theorized that the brightly colored plastron of hatchlings might be a warning coloration.

*Parasites.* — Endoparasites of loggerhead musk turtles include roundworms, tapeworms, nematodes, trematodes, lung flukes, and protozoans (Johnson, 1967; Gibbons and Esch, 1970; Ernst and Ernst, 1977, 1978; Cox et al., 1988; Kirkpatrick, 1997). Wild-caught specimens are sometimes covered with algae (Ernst and Barbour, 1972), and are often infested with leeches (Ernst et al., 1994; RTZ, *pers. obs.*).

## THREATS

Increased boat traffic on rivers and springs disturbs the habitat of these turtles. The wakes of speedboats and/or commercial tugboats pulling barges causes increased turbidity of the water and shore-line erosion, thus adversely impacting aquatic vegetation and reducing the long-term suitability of the habitat.

Musk turtles are frequently caught on baited hooks by fishermen (Carr, 1952), which often leads to the death or serious injury of the individual when the hook is removed. Several similar observations were made on the Apalachicola River when fishermen on a sand bar were seen cutting the heads off adult *S. minor* in order to retrieve their hooks (RTZ, *pers. obs.*).

Florida Game and Freshwater Fish Commission regulations allow the taking of two *S. minor* per person per year, without permit or license required. The Florida Nongame Wildlife Regulations of 2000–2001 also state: "no person shall possess more than 50 eggs taken from the wild in the aggregate of species of freshwater turtles native to Florida. The purchase or sale of turtle eggs taken from the wild is prohibited"(Florida Fish and Wildlife Conservation Commission, 2001). The state of Tennessee also permits the taking of two loggerhead musk turtles per year without restriction, and the capture of turtles "manually throughout the year or by use of baited hooks, bows, dip nets, traps, or spearing" (Tennessee Wildlife Resources Agency, 2002). Both states prohibit the sale or capture for sale of loggerhead musk turtles. All freshwater turtles not on Georgia's Protected Species List (including *S. minor*) may be freely hunted or trapped in that state (Georgia Department of Natural Resources, 2003). The effect of unregulated harvesting on wild populations of loggerhead musk turtles is unknown. However, since this species is readily accessible to snorklers in clear spring runs, it has been a regular target of commercial collectors who take animals for the pet trade. Large numbers were taken from Ichetucknee spring run between US Hwy 27 and the Santa Fe River for the pet trade in the late 1980s (K.M. Enge, *pers. comm.* to P.A. Meylan). It is not known if commercial collecting on this scale continues at this time. Finally, automobile traffic sometimes causes road mortality of nesting females (RTZ and JBI, *pers. obs.*).

## STATUS

The status of *S. minor* has been reevaluated using the criteria set out by the Florida Committee on Rare and Endangered Species. Those definitions are available in the preface to Moler (1992). While some loggerhead musk turtle populations seem to be stable in certain river systems, there is not enough known about the overall abundance or rarity of this species in Florida to warrant placing it into a particular protective status. Until more data are available it is recommended that this species be listed as Status Undetermined (SU). The Nature Conservancy has *S. minor* on its Natural Heritage Program List as "apparently secure globally, though it might be quite rare in parts of its range, especially at the periphery" (LeGrand and Hall, 1999). The Nature Conservancy estimates that there are over a thousand extant populations of loggerhead musk turtle in the wild, but assigns it to Status Unknown (LeGrand and Hall, 1999). However, given its ability to thrive and reproduce in suitable freshwater habitat, *S. minor* is not likely to become seriously threatened in Florida (or other portions of its range) unless the water quality in the rivers and streams are degraded, or the environmental health of the ecosystem is severally damaged by development activities.

## CONSERVATION OPTIONS AND SOLUTIONS

Public education is essential if turtle populations are to survive in Florida. State Parks and non-profit nature centers should post fact sheets that provide general information about the life history and the role that turtles play in the aquatic ecosystems. Turtles are a key species in the food chain and the general public should be made aware of their importance through sound educational programs. Certain mammalian predators, such as raccoons and foxes, are on the increase. Predator control measures should be considered to prevent the loss of nesting females and their eggs. Since loggerhead musk turtles are easily seen in clear spring runs, they are highly susceptible to commercial collection at these sites. State regulatory agencies responsible for wildlife

protection should monitor the number of individual loggerhead musk turtles (and other herpetofauna) entering the international pet trade from the wild in Florida.

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## LITERATURE CITED

AGASSIZ, L. 1857. Contributions to the natural history of the United States of America. Vol. 1. Boston, Massachusetts: Little, Brown and Co, 452 pp.

ASHTON, R.E., JR. AND ASHTON, P.S. 1985. Handbook of the reptiles and amphibians of Florida. Part 2. Lizards, turtles and crocodilians. Miami, Florida: Windward Publishers, 191 pp.

BELKIN, D.A. 1968. Aquatic respiration and underwater survival of two freshwater turtle species. Respiration Physiology 4:1-14.

BELS, V.L. AND CRAMA , Y. J. M. 1994. Quantitative analysis of the courtship and mating behavior in the loggerhead musk turtle *Sternotherus minor* (Reptilia: Kinosternidae) with comments on courtship behavior in turtles. Copeia 1994:676-684.

BELS, V.L. AND LIBOIS, R. 1983. Etude comparée des parades sexuelles de quelques espècies de cheloniens: *Pelomedusa subrufa subrufa* (Lacépède), *Sternotherus minor* (Agassiz) et *Kinixys belliana nogueyi* (Bell). Cashiers d'Ethologie Appliquée 3:39-58.

BERRY, J.F. 1975. The population effects of ecological sympatry on musk turtles in northern Florida. Copeia 1975:692-700.

BRAMBLE, D.M., HUTCHISON, J.H., AND LEGLER, J.M. 1984. Kinosternid shell kinesis: structure, function, and evolution. Copeia 1984:456-475.

BRITSON, C.A., AND GUTZKE, W. H. N. 1993. Antipredator mechanisms of hatchling freshwater turtles. Copeia 1993:435-440.

CAMP, C.D. 1986. *Sternotherus minor* (loggerhead musk turtle). Size. Herpetological Review 17:89, 91.

CARR, A.F. 1952. Handbook of Turtles. The Turtles of the United States, Canada, and Baja California. Ithaca, New York: Cornell University Press, 542 pp.

CONANT, R. AND COLLINS, J.T. 1998. A Field Guide to Reptiles and Amphibians: Eastern and Central North America. Third Edition-Expanded. Boston, Massachusetts: Houghton Mifflin, 492 pp.

COX, W.A. 1978. Reproduction, growth, and life history strategies in the musk turtle (*Sternotherus minor*) in north Florida. Ph.D. Dissertation. University of Alabama, Birmingham.

COX, W.A. AND MARION, K.R. 1978. Observations on the female reproductive cycle and associated phenomena in spring-dwelling populations of *Sternotherus minor* in North Florida (Reptilia: Testudines). Herpetologica 34:20-33.

COX, W.A. AND MARION, K.R. 1979. Population structure and survivorship in the musk turtle, *Sternotherus minor,* in a North Florida spring run (Reptilia: Chelonia). Bulletin of the Association of Southeastern Biologists 28:84.

COX, W.A., NOWAK, M.C. AND MARION, K. R. 1980. Observations on courtship and mating behavior in the musk turtle, *Sternotherus minor*. Journal of Herpetology 14:200-204.

COX, W.A., WYATT, S.T., WILHELM, W. E., AND MARION, K. R. 1988. Infection of the turtle, *Sternotherus minor*, by the lung fluke, *Heronimus mollis*: incidence of infection and correlations to host life history and ecology in a Florida spring. Journal of Herpetology 22:488-490.

COX, W.A., HAZELRIG, J. B., TURNER, M.E., ANGUS, R.A., AND MARION, K. R. 1991. A model for growth in the musk turtle, *Sternotherus minor*, in a north Florida spring. Copeia 1991:954-968.

DITMARS, R. 1936. The Reptiles of North America: a review of the crocodilians, lizards, snakes, turtles, and tortoises inhabiting the United States and northern Mexico., Garden City, New York: Doubleday and Company, 476 pp.

DUNDEE, H.A. AND ROSSMAN, D.A. 1989. The Amphibians and Reptiles of Louisiana. Baton Rouge, Louisiana: Louisiana State Univ. Press, 300 pp.

EHRENFELD, J. G. AND EHRENFELD, D. W. 1973. Externally secreting glands of freshwater and sea turtles. Copeia 1973:305-314.

ENGE, K. M. AND FOSTER, D. R. 1986. Life history notes: *Sternotherus minor minor* (loggerhead musk turtle). Size. Herpetological Review 17:25.

ERNST, C.H. AND BARBOUR, R.W. 1972. Turtles of the United States. Lexington, Kentucky: University Press, 347 pp.

ERNST, C.H. AND ERNST, E.M. 1978. Synopsis of protozoans parasitic in native turtles of the United States. Bulletin of the Maryland Herpetological Society 15:1-15

ERNST, C.H., MILLER, J. L., MARION, K. R., AND COX, W.A. 1988. Comparisons of shell morphology among turtles of the *Kinosternon minor* complex. American Midland Naturalist 120:282-288.

ERNST, C.H., LOVICH, J. E., AND BARBOUR, R.W. 1994. Turtles of the United States and Canada. Washington D.C.: Smithsonian Institution Press, 578 pp.

ERNST, E.M. AND ERNST, C.H. 1977. Synopsis of helminths endoparasitic in native turtles in the United States. Bulletin of the Maryland Herpetological Society 13:1-75.

ESTRIDGE, R.E. 1970. The taxonomic status of *Sternotherus depressus* (Testudinata, Kinosternidae) with observations on its ecology. Master's thesis, Auburn Univ., Auburn, Alabama.

ETCHBERGER, C.R. AND EHRHART, L. 1987. The reproductive biology of the female loggerhead musk turtle, *Sternotherus minor minor*, from the southern part of its range in Central Florida. Herpetologica 43:66-73.

ETCHBERGER, C.R. AND STOVALL, R.H. 1990. Seasonal variation in the testicular cycle of the loggerhead musk turtle, *Sternotherus minor minor*, from Central Florida. Canadian Journal of Zoology 68:1071-1074.

EWERT, M.A. 1985. Embryology of turtles. In: Gans, C., Billett, F., and Maderson, P. F. A. (Eds.). Biology of the Reptilia Vol. 14. New York, New York: John Wiley & Sons, pp 76-267.

EWERT, M.A., AND NELSON, C.E. 1991. Sex determination in turtles: diverse patterns and some possible adaptive values. Copeia 1991:50-69.

FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION. 2001. Hunting Regulations Summary. [http://floridaconservation.org]

FOLKERTS, G.W. 1967. Notes on a hybrid musk turtle. Copeia 1967:479-480.

FOLKERTS, G.W. 1968. Food habits of the striped-necked musk turtle, *Sternotherus minor peltifer* Smith and Glass. Journal of Herpetology 2:171-173.

GATTEN, R.E., JR. 1984. Aerobic and anaerobic metabolism of freely-diving loggerhead musk turtles (*Sternotherus minor*).

Herpetologica 40:1-7.

GEORGIA DEPARTMENT OF NATURAL RESOURCES, 2001. General Hunting Regulations. [http://www.georgiawildlife.dnr.state.ga.us/]

GIBBONS, J. W., AND ESCH, G. W. 1970. Some intestinal parasites of the loggerhead musk turtle (*Sternotherus m. minor*). Journal of Herpetology 4:79-80.

GUNTERMANN, J. 1998. Beobachtungen an *Sternotherus minor minor* in natürlichen Lebensräumen in Florida. Emys 5:4-16.

GUYER, C., AND HERNDON, K. A. 1992. Population analysis of *Sternotherus minor peltifer*. Journal of the Alabama Academy of Science 63:48.

HENSLEY, F.R. 1994. *Sternotherus minor* (loggerhead musk turtle). Foraging depth. Herpetological Review 26:99.

HUESTIS, D.L., AND MEYLAN, P.A. 2004. The turtles of Rainbow Run (Marion County, Florida): observations on the genus *Pseudemys*. Southeastern Naturalist 3:595-612.

IVERSON, J. B. 1977a. Geographic variation in the musk turtle *Sternotherus minor*. Copeia 1977:502-517.

IVERSON, J. B. 1977b. *Sternotherus minor* (Agassiz). Loggerhead musk turtle. Catalogue of American Amphibians and Reptiles 195:1-2

IVERSON, J. B. 1977c. Reproduction in freshwater and terrestrial turtles of north Florida. Herpetologica 33:205-212.

IVERSON, J. B. 1978. Reproductive cycle of female loggerhead musk turtles (*Sternotherus minor minor*) in Florida. Herpetologica 34:33-39.

IVERSON, J.B. 1982. Biomass in turtle populations: a neglected subject. Oecologia 55:69-76.

IVERSON, J.B. 1992. A Revised Checklist with Distribution Maps of the Turtles of the World. Richmond, Indiana: Privately Printed, 363 pp.

IVERSON, J.B. 1998. Molecules, morphology and turtle phylogenetics (Family Kinosternidae). Chelonian Conservation and Biology 3:113-117.

IVERSON, J.B. AND ETCHBERGER, C.R. 1989. The distributions of the turtles of Florida. Florida Scientist 52:119-144.

IVERSON, J.B. AND PAULL, R. C. 2004. Musk Turtle. Sumterville, Florida: Green Nature Books, 78 pp.

JACKSON, C.G. 1965. Carapace erosion in the loggerhead musk turtle, *Sternotherus minor minor* Agassiz. Herpetologica 20:279-281.

JACKSON, C.G. 1969. Agonistic behavior in *Sternotherus minor minor* Agassiz. Herpetologica 25:53-54.

JACKSON, J.F. 1988. Crevice occupation by musk turtles: taxonomic distribution and crevice attributes. Animal Behavior 36:793-801.

JACKSON, J.F. 1990. Evidence for chemosensor-mediatiated predator avoidance in musk turtles. Copeia 1990:557-560.

JOHNSON, C.A. 1967. *Sternotherus minor peltifer* (Chelonia) a new host record for *Heronimus chelydrae* MacCallum, 1902 (Trematoda: Digenea). Journal of Parasitology 53:617.

KIRKPATRICK, D.T. 1997. The Biology, Husbandry, and Health Care of Reptiles. Vol. II: The Husbandry of Reptiles. Neptune City, New Jersey: T.F.H. Publications.

LEGRAND, H.E. AND HALL, S.P. 1999. Natural Heritage Program List of the Rare Animal Species of North Carolina. Raleigh, North Carolina: The Nature Conservancy.

LEHMANN, H. 1984. Ein Zwillingsschlupf bei *Sternotherus minor minor* (Agassiz, 1857). Salamandra 20:192-196.

MARCHAND, L. J. 1942. A contribution to a knowledge of the natural history of certain freshwater turtles. Master's Thesis, Univ. Florida, Gainesville.

MESHAKA, W., AND GALLO, N. 1990. Geographic distribution: *Sternotherus minor* (loggerhead musk turtle). Herpetological Review 21:95.

MEYLAN, P.A., STEVENS, C.A., BARNWELL, M.E., AND DOHM, E.D. 1992. Observations on the turtle community of Rainbow Run, Marion Co., Florida. Florida Scientist 55:219-228.

MITCHELL, J. C. 1994. The Reptiles of Virginia. Washington D.C.: Smithsonian Institution Press, 352 pp.

MOLER, P.E. 1992. Rare and Endangered Biota of Florida. Vol. III. Amphibians and Reptiles. Gainesville, Florida: University Press Florida, 291 pp.

MOUNT, R.H. 1975. The Reptiles and Amphibians of Alabama. Auburn, Alabama: Auburn University Agricultural Experimental Station, 347 pp.

NAGLE, R. D., BURKE, V. J., AND CONGDON, J.D. 1998. Egg components and hatchling lipid reserves: Parental investment in kinosternid turtles from the southeastern United States. Comparative Biochemistry and Physiology 120B:145-152.

NEILL, W. T. 1948. Use of scent glands by prenatal *Sternotherus minor*. Herpetologica 4:148.

NOLAN, D. 1991. The maintenance and breeding of the loggerhead musk turtle *Sternotherus minor minor* (Agassiz, 1857). Testudo 3(3):1-4.

ONORATO, D. 1996. The growth rate and age distribution of *Sternotherus minor* at Rainbow Run, Florida. Journal of Herpetology 30:301-306.

PACKARD, M. J., HIRSCH, K. F., AND IVERSON, J. B. 1984. Structure of shells from eggs of kinosternid turtles. Journal of Morphology 181:9-20.

PALMER, W. M., AND BRASWELL, A. L. 1995. Reptiles of North Carolina. Chapel Hill, North Carolina: University of North Carolina Press, 412 pp.

PRITCHARD, P. C. H. 1989. The Alligator Snapping Turtle: Biology and Conservation. Milwaukee, Wisconsin: Milwaukee Public Museum, 104 pp.

ROGNER, M. 1996. Schildkröten 2. Hürtgenwald, Germany: Heidi-Rogner-Verlag. 265 pp.

RÖDEL, M.O. 1989. Haltung und Zucht der Kleinen Moschusschildkröte *Sternotherus minor minor* (Agassiz, 1857). Aquarama 4:46-49.

SACHSSE, W. 1977. *Sternotherus m. minor*, seine Nachzucht und die damit verbundenen biologischen Beobachtungen (Reptilia: Testudines: Kinosternidae). Salamandra 13:157-165.

SCHILDE, M. 2001. Schlammschildkröten: *Kinosternon*, *Sternotherus*, *Claudius* und *Staurotypus*. Münster, Germany: Natur und Tier Vierlag, 133 pp.

SCHMIDT, K. P. 1953. A check list of North American amphibians and reptiles. Sixth Edition. Chicago, Illinois: University of Chicago Press, 280 pp.

SCOTT, A.F., SUTTON, S., AND WILLIAMSON, S. 2000. New county records of amphibians and turtles from the western highland rim of central Tennessee. Herpetological Review 31:117-118.

SEIDEL, M.E. AND LUCCHINO, R.V. 1981. Allozymic and morphological variation among the musk turtles *Sternotherus carinatus*, *S. depressus* and *S. minor* (Kinosternidae). Copeia 1981:119-128.

SEIDEL, M.E., IVERSON, J. V., AND ADKINS, M. D. 1986. Biochemical comparisons and phylogenetic relationships in the family Kinosternidae (Testudines). Copeia 1986:285-294.

SMITH, H.M., AND GLASS, B.P. 1947. A new musk turtle from southeastern United States. Journal of the Washington Academy of Sciences 37:22-24.

STEJNEGER, L. 1923. Rehabilitation of a hitherto overlooked species of musk turtle of the southern states. Proceedings of the U.S. National Museum 62:1-3.

STEVENSON, D. AND CROWE, D. 1992. Geographic distribution: *Sternotherus minor minor*. Herpetological Review 23:88.

STRAUCH, A. 1862. Chelonische Studien, mit besonderer Beziehung auf die Schildkrötensammlung der kaiserlichen Akademie der Wissenschaften zu St. Petersburg. Mémoirs de l'Académie Impériale des Sciences de Saint-Pétersburg 7(5)7:1-196.

TENNESSEE WILDLIFE RESOURCES AGENCY. 2002. Tennessee Animal Biogeographic System, TABS. [http://fwie.fw.vt.edu/TN/TN07092.htm]

TINKLE, D.W. 1958a. The systematics and ecology of the *Sternothaerus carinatus* complex (Testudinata: Chelydridae). Tulane Studies in Zoology 6(1):1-56.

TINKLE, D.W. 1958b. Experiments with censusing of southern turtle populations. Herpetologica 14:172-175.

TINKLE, D.W. AND WEBB, R.G. 1955. A new species of *Sternotherus* with a discussion of the *Sternotherus carinatus* complex (Chelonia, Kinosternidae). Tulane Studies in Zoology 3(3):53-67.

WALKER, D., BURKE, V.J., BARAK, I., AND AVISE, J.C. 1995. A comparison of mtDNA restriction sites vs. control region sequences on phylogeographic assessment of the musk turtle (*Sternotherus minor*). Molecular Ecology 4:365-373.

WILLIAMSON, G.K. AND MOULIS, R.A. 1994. Distribution of Amphibians and Reptiles in Georgia. Savannah Science Museum Special Publication 3:2 volumes.

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