live wild-caught creatures increase demand. Often articles are actually telling people precise localities where they can collect range-restricted specific species without breaking local wildlife laws. What was a cottage industry in the 1950s and 1960s is now a major multimillion-dollar international business network. Collectively all this is a growing ethical disgrace, and to imply it's anything else is beyond ridiculous. This cannot possibly be helping conservation.

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Soil Temperature and Nest Site Selection by the Eastern Box Turtle, *Terrapene carolina carolina*

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When given a choice, in this controlled study, female eastern box turtles (*Terrapene carolina carolina* Linnaeus 1758) consistently chose insolated, warmer soil in which to dig their nests. The behavior has evident benefit for egg incubation, but because canopy openings in the increasingly fragmented terrestrial habitats that remain for box turtles are often sites of such human activity as plowing, mowing, and logging, it is hazardous to females as they move to, and search for nest sites within, such insolated areas. Large roadless sanctuaries of perhaps more than 1000 ha are needed to slow the decline of this and other terrestrial chelonians.

The United States and Canada have 20 native chelonian genera (Ernst et al. 1994). Among these, *Terrapene*, North America's box turtles, ranks near the bottom in the number of eggs in their clutches (from appendix III, Kohler 2005).

Box turtle densities are in decline and do not recover well from losses (Williams 1961; Schwartz and Schwartz 1974; Murphy 1976; Schwartz et al. 1984; Williams and Parker 1987; Doroff and Keith 1990; Lieberman 1994; Breisch 1997; McCollough 1997; Tyning, 1997a; Klemens 2000; Miller 2000; Lodato and Hulvershorn 2001; Bowen et al. 2004; Niederriter and Roth 2004), even when the populations are within vast, well-protected tracts (Adler 1970; Stickel 1978, 1989; Halgren-Scaffidi 1986; Hall et al. 1999). Low egg (hence hatchling) production contributes to that difficulty (Seigel 2005).

Because of marked decline throughout its range (e.g., Tyning 1997b) *Terrapene* was added to appendix II of CITES (Convention on International Trade in Endangered Species) in 1994 (e.g., Lieberman 1994; Pritchard 1995) in an effort to reduce adult losses to the international pet trade. Although retaining a high density of adults in a habitat is the most important factor in stabilizing and perpetuating populations of late-maturing animals like chelonians (e.g., Congdon et al. 1993, 1994, 2001; Brooks 1997; Crouse 1999; Musick 1999; Miller 2001; Amie 2002; Belzer 2002; Reed et al. 2002; Yeoman 2002; Reed and Gibbons 2003; Bowen et al. 2004; Seigel 2005), improved hatching success might make a small contribution to population stability because survival of eggs and juvenile turtles is so low (e.g., Madden 1975; Harless and Morlock 1989; Iverson 1991; Dodd 2001; Belzer et al. 2002; Aresco 2004; Draud et al. 2004; Feinberg 2004; Flitz and Mullin 2006).

Dodd (2001) and Flitz and Mullin (2006) recently noted the deficient understanding of eastern box turtle (*Terrapene carolina carolina* L.) nest site selection in relation to reproductive success. In 1995 we began a preliminary investigation of nest substrate preferences by *T. carolina carolina*. We dug 3 adjacent 2 × 2 m, 25-cm-deep depressions (cribs) inside a 700-m^2 nest-study pen (all measures approximate) on a south-facing slope at the McKeever Environmental Learning Center in Mercer County of northwestern Pennsylvania. We filled the 3 cribs with different mixtures that included forest humus, clay, peat moss, and/or creek sand. During the course of that study, we ascertained no substrate preferences in that partially shaded enclosure because the females always chose to nest in the regions that received the longest insolation, regardless of the substrate.

In 1995 and 1996, the northwestern corner of the enclosure received the most uninterrupted insolation (approximately 3 hours in late morning), and the females dug all (n = 4) of their nests in and around that corner during those 2 years. The felling of several large trees outside the enclosure in February 1997, thereafter exposed the eastern crib to the longest uninterrupted insolation (approximately 4.5 hours in midafternoon) within the enclosure. During 1997 and the ensuing 4 years of the investigation, the females never again used the western area to nest; they dug 2 nests near the eastern side of (but not in) the middle crib; and they dug the other 36 nests in, or along the borders of, the eastern crib. Insolation, rather than substrate, appeared to be the primary criterion for nest site choice in that shady habitat. That would be an advantageous behavior in wooded habitats because insolation is the thermal source for incubating box turtle eggs.

Because *T. carolina carolina* typically starts to dig nests in early evening (e.g., Ditmars 1934; Allard 1935, 1948; Stickel 1950; Murphy 1976; Congello 1978), we measured the 3 cribs'

Table 1. Cumulative temperature ranges (°C) for west (W) and east (E) beds.

	1–30 Jun 2002		1–30 Jun 2003		9 Jun–18 Aug 2004	
Bed	W[a]	E	W[a]	E[a]	W	E[a]
High	29.0	27.1	29.9	29.8	27.2	30.7
Low	12.3	12.0	13.1	13.2	12.3	12.9

[a] Sun-exposed bed.

soil temperatures (at 7-cm depth) in the early evening on 5 different dates during June 2001. This allowed us to evaluate our hypothesis that there is a positive association between insolation and soil warmth at nesting time. Indeed, soil in the eastern crib was always warmer (1.5°–3°C) than that in the other two cribs. This suggested that the females' nesting in sunnier sites was actually a choice for warmer soil.

Box turtle selection of sunny sites for nesting has been reported previously (e.g., Congello 1978; Messinger and Patton 1995). More recently, Flitz and Mullin (2006) confirmed that open habitat, with exposed ground and higher light intensity (soil temperatures were not taken), was preferred by *T. carolina carolina* for nesting. In discussing Congello's (1978) report of eastern box turtles nesting in sunny locations, Dodd (2001, p. 97) suggested an influence of soil temperature in site selection (also see Flitz and Mullin, 2006). Jude Holdsworth, field associate for the New York Department of Environmental Conservation, reports (*pers. comm.,* July 2003) that females in the NY *T. carolina carolina* population that she studies have a predilection for digging in the black sooty substrate near railroad tracks traversing the habitat, even though rocks there make it unsuitable for nesting. Similarly, Roy Nagel of Juniata College found that map turtles (*Graptemys geographica* Le Sueur) in central Pennsylvania prefer to dig in coal slag rather than adjacent sand flats (Lewerenz 2001). The dark coal slag was 3°–5ºC warmer than the sand.

To more rigorously assess the hypothesis that soil temperature is an important factor in nest site selection by the eastern box turtle, we conducted a study (using a less shaded and more controlled environment than that at the McKeever Center) during 2002 through 2004.

Materials and Methods

The study habitat was a 150 m^2 (15 m E–W × 10 m N–S) fenced plot of suburban, grassy back yard, bordering a 16-ha wooded park on the outskirts of Oil City, Venango County, Pennsylvania. The dominant plants in the yard were ground ivy (*Glechoma bederacea* L.), various golden rods (*Solidago* spp. L.), orchard grass (*Dactylis glomerata* L.), and various fescues (*Festuca* spp. L.). We dug 2 adjacent 1.7 × 1.7 m plots into the sunniest portion of the yard, and tilled them into soft soil beds with a 25-cm-wide strip of grass left between them. We did not alter the soil composition beyond the tilling and removing most roots and stones. We retilled the soil in both beds in late May of each year and left the remainder of the enclosure unmowed.

On sunny days, both adjacent beds received about 6 hours of insolation (starting approximately 0930 hours, when the sun first cleared the roof of a bordering building; ending approximately 1530 hours when the sunlight became highly dappled as the sun fell behind nearby tree tops).

In 2002 and 2004, we suspended angled, opaque tarps on poles extending from the adjacent building's eaves to prevent most of the sun from reaching one bed. In 2002, the eastern bed was shaded; in 2003 neither bed was shaded; in 2004 the western bed was shaded. The tarps did not impede rain fall.

In each of the 3 years of this study, we housed 6–9 adult female *T. carolina carolina*, from our populations involved in repatriation and head start studies (e.g., Belzer 1999, 2002; Belzer et al. 2002), in the Oil City enclosure during the June–July nesting season.

We obtained daily readings and cumulative ranges of soil temperatures (at 7-cm depth) from in situ KM12 minimum–maximum memory thermometers (Comark Ltd., Stevenage, Hertfordshire, UK) left in each bed.

We used the two-tailed Wilcoxon matched-pairs signed-ranks test (http://faculty.vassar.edu/lowry/wilcoxon.html) to test the significance of soil temperature differences. To test the significance of differences in nest site choices, we used the two-tailed sign test (http://www.graphpad.com/quickcalcs/binomial1.cfm).

Results

Nest site choices

Consistent with reports that *T. carolina carolina* prefers to nest in open soil that is free of obstructions (e.g., Allard 1948; Murphy 1976; Flitz and Mullin 2006), our females dug all nests (n = 14) during this 3-year study in the tilled beds.

They dug all 6 of their 2002 nests in the unshaded (western) bed. In 2003, they distributed 5 nests between the 2 unshaded beds (2 nests in the western, 3 in the eastern). They dug all 3 of their 2004 nests in the unshaded (eastern) bed.

Thus, when given a choice between insolated and shaded beds, our females always chose sun-exposed soil in which to nest (p = 0.004 for this difference, two tailed). The exact 95% confidence interval for this proportion (9 of 9) extends from 0.6637 to 1.0000. When both beds were insolated, there was no significant difference in nest distribution *(p*

Table 2. Selected soil temperature comparisons (°C) at 7-cm depth between insolated (west) bed and shaded (east) bed in 2002.

		Soil temperature		
Date	Time (h)	West	East	Air temperature (nearest whole °C)
Field note 9–10 Jun, sunny; wet soil from rain 3 d ago				
11 Jun	2030	23.1[a]	21.3	21
12 Jun	0230	20.1	19.6	19
12 Jun	0800	19.0	18.3	17
14 Jun	2100	19.5	18.6	19 (light rain)
15 Jun	0800	16.7	15.9	15
Field note 13 Jun-16 Jun, overcast and cool; 17 Jun, sunny				
17 Jun	0900	13.9	13.1	12
17 Jun	1400	23.1	15.9	24
17 Jun	2000	22.4[a]	18.1	21
21 Jun	1930	23.8[a]	20.6	21
22 Jun	0730	18.8	17.5	17

[a] Nesting in progress.

= 1.000, two tailed). The exact 95% confidence interval of this proportion (2 of 5) extends from 0.0527 to 0.8534.

Soil temperatures

From 11 June till 6 July 2002, we recorded 21 sets of temperatures for the 2 beds, taken at various times between 0230 and 2145 hours. During the period 15 June to 25 June 2003, we recorded 20 sets of temperatures taken between 0620 and 2245 hours. In 2004, we collected 19 temperature sets between 0730 and 2000 hours from 9 June till 17 August. In every instance, for the 2002 and 2004 sets, the temperature in the insolated bed was warmer than that in the shaded bed ($p < 0.0001$). In 2003 (both beds insolated), there was no significant difference between the two beds ($p > 0.32$). Temperature differences in 2003, when present (14 of the 20 sets), were small (0.1°–0.9°C), with each bed at times being the warmer.

Cumulative temperature ranges (logged by the in situ maximum–minimum thermometers) for the west and east beds for each year are shown in Table 1.

To illustrate that weather and time modulate the insolating effect, Table 2 summarizes field notes from selected dates in mid-June 2002 (the year when only the western bed received sun).

Discussion

The findings from this study support the hypothesis that soil temperature is an important criterion for nest site selection by *T. carolina carolina*. Females from this species must have some means of evaluating soil temperature. We have seen some of our female box turtles display stereotypical prenesting movements that might be involved in monitoring a soil characteristic like temperature. During this behavior, the female confines her movements to a small area (approximately 1 m^2). She intermittently walks a short distance, then stops before moving again. These movements can go on for more than an hour, during which she repeatedly doubles back, transects, circles, and otherwise performs a convoluted search of the area. During the pauses she often extends her neck, lowers her head and touches the soil with the skin of her chin and/or tip of her beak (or sometimes places one cheek onto the soil surface and then, turning her head, repeats the touch with her other cheek). Mandibular movements heard in 2 such instances raise the possibility that she may also sample the soil orally. In some cases the female, after chin-touching a particular spot of soil, reached out with a forefoot and scratched the soil, or brushed away light debris, before again placing her chin upon the surface (as if to be certain that it was the actual soil surface she was assessing). Others have reported this prenesting ("soil-nuzzling") behavior in Terrapene (e.g., Foust 1992; Messinger and Patton 1995), and Morjan and Valenzuela (2001) reviewed literature demonstrating that it is a behavior found across many chelonian genera.

In some of our observations, soil-nuzzling continued until the female started to dig. In other instances, when the female did not nest after her close examination of the soil, she did sometimes return to the same site the next evening to dig her nest there.

Some of us observing this behavior have suspected that it is used to assess soil temperature. Morjan and Valenzuela (2001), however, conducted a careful study and found that it does not serve that purpose in the painted turtle (*Chrysemys picta* Schneider).

Whatever the mechanism, differences in soil temperature can evidently be detected by many turtles. Seeking sunny areas, while advantageous for egg incubation, now increases the risk of female death as they move to and search within open spaces in today's fragmented habitats, because insolated areas are often sites of such human activity as logging, cultivation, and mowing. Such hazard to females has already been documented for some species (Gibbs and Shriver 2002; Gibbs and Steen 2005). Roadless sanctuaries of at least 1000 acres (450 ha), as suggested by Michael Klemens at the 30–31 October 1999 symposium on Conservation and Ecology of Turtles of the Mid-Atlantic Region (National Wildlife Visitor Center, Patuxent Research Refuge, Laurel, MD), or 1000 ha according to Gibbs and Shriver (2002), are needed to protect terrestrial turtle populations. Such habitat provisions need to be made quickly, before further declines in population densities erode opportunities for surviving individuals to regularly find mates (Belzer 2002).

The use of open, insolated sites for nesting posits a selection pressure for evening digging by box (and other) turtles. Nest digging takes a minimum of a few hours, and we have seen our females, when struggling with impediments like roots or small pebbles just out of reach in the bottom of the hole they are digging, dig for 8 hours or more. Such an undertaking during a hot day in June or July, on a sun-exposed spot, could end in lethal hyperthermia.

Ditmars (1934, p. 430) reported another reasonable hypothesis for evening nest digging by eastern box turtles: avoidance of male courtship. Courtship in *Terrapene* can be aggressive, lengthy, and very persistent and would certainly interfere with the female's attempts to nest. By dusk, each night, eastern box turtles generally settle into their forms (shallow depressions that they dig into surface soil) for the evening; only females searching for nest sites are active after that.

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The Red-Eared Slider Turtle (*Trachemys scripta elegans*) in New Zealand

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New Zealand (NZ) is unique in having no native turtles. Any turtles present in NZ have been imported as personal pets or via the pet trade before 1965. Over the past year there has been considerable misinformation about red-eared slider turtles (*Trachemys scripta elegans*) in the New Zealand media. The purpose of this presentation is to document the facts we do have about these turtles from overseas, and the research that has been done here.

History of the New Zealand Market

Red ears were imported into New Zealand from Louisiana, USA, until 1965. A ban on importation was introduced in 1965 because the hatchlings were found to be carriers of several varieties of *Salmonella* not previously known in NZ. However, by the time the ban was instituted, 30,000 animals had already been imported and sold, so those alien species of *Salmonella* were already widely distributed.

The imported turtles came from turtle farms where they were raised in enormous concentrations (10,000–30,000 adults per surface acre). The animals were fed processed food but large amounts of *Salmonella*-rich offal and wild water plants from surrounding swamps were also consumed. These contaminated the stagnant water with a host of bacteria, including multiple *Salmonella* serotypes. Waters in surrounding swamps were also contaminated with *Salmonella* of similar varieties. Virtually all the hatchlings were carriers of *Salmonella* (Chiodini and Sundberg 1981). The *Salmonella* was acquired as the eggs passed through the cloacae or were deposited in the contaminated soils at the farms.

After the importation ban came into force, smuggling continued until the mid-1980s with 1000–2000 animals being imported per year. After that, back-yard breeders became common throughout New Zealand. After my first survey of NZ breeders in 1997, I concluded that about 2000 hatchlings were being sold per year and there was enough demand to sell another 300–500 animals at a retail price of NZ$90–$100 each. At that time there were 4 main breeders and about 20 smaller ones.

My survey of breeders in 2005 came to similar conclusions. The retail price varied from NZ$70–$100 retail. Output was still about 2000 animals per year, which seemed to be meeting demand.

The International Situation and Origin of the Red-Ear "Problem"

The Louisiana, USA, turtle farms have exported between 8 million and 12 million animals annually for many years. In later years Korea imported up to 1.3 million per year, Italy about a million, and Japan 0.6 million. Taiwan, South Africa, Israel, Australia, Thailand, Cambodia, and other European Union countries were also big importers. In 1997 the importation of red-ears was banned in the European Union. China has now replaced Korea as the major importer. Red-ears have been able to reproduce in the "wild" in southern France (Cadi et al. 2004) and possibly Spain and Taiwan but not in northern France, central Italy (Luiselli et al. 1997), or England.

Millions of these animals are sold in Asia for Buddhist "Mercy Ceremonies" in which the turtle is marked and