but were smaller and swam slower than those from the developmentally equivalent constant temperature. (2) Therefore, developmentally equivalent temperature regimes do not necessarily result in offspring with equivalent phenotypes. (3) Because most softshells nest in sunny sites, these results may be interpreted in a natural context. (4) Interpretations stemming from constant temperature incubation studies may need to be re-examined.

The present study was the first designed to test the relative effects of constant and fluctuating temperatures on hatchling phenotypes in reptiles. Findings indicate that interpretations of published incubation studies utilizing constant temperatures may need to be modified. Future incubation studies should incorporate fluctuating temperature regimes, because egg temperatures fluctuate in nature, and because the technology for simulating natural egg temperatures is readily available.

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Mercury Concentration in the Scutes of Black Sea Turtles, *Chelonia mydas agassizii*, in the Gulf of California. Linnaeus Fund Research Report

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Anthropogenic mercury contamination of aquatic systems is a serious environmental problem (Laws, 1993), although little is known regarding its accumulation and effects on sea turtles. Research is needed to rapidly and humanely evaluate the effects of mercury and other environmental pollutants on sea turtle health. Mercury and other heavy metals have been found to disrupt normal neurological and physiological function in many species, leading to their stranding, death, and further population decline (Regan et al., 1989; Gottschalk et al., 1991; Colborn et al., 1996). In species in which this biologically nonessential metal has been studied, it impairs growth and reproduction, neurological development and motor coordination, vision, hearing, respiration, blood chemistry, metabolism, and osmoregulation (Eisler, 1987). Additionally, because of its high lipid solubility, mercury has a particular affinity for the central nervous system, where it interrupts the sulfhydryl enzymes of protein synthesis critical to normal neurological function (Osweiler, 1996).

Detection of mercury and other heavy metals in keratinized tissues has been used as an indicator of biotic accumulation in humans (Willhelm et al., 1991), domestic animals (Sakai et al., 1995), and wildlife (Mason et al., 1986). Tissues such as hair, skin, nails, and feathers are rich in sulfhydryl-containing amino acids which avidly bind metals. The carapace of sea turtles is covered by keratinized scutes (Mader, 1996). Collection of keratinized tissue from the scutes of sea turtles has been shown to be a highly sensitive, non-invasive sampling technique for monitoring mercury (Presti et al., in press). It was demonstrated that mercury concentration in the scutes was on average 36 times higher than in the blood. Mercury concentrations in the scutes were also 5.3 times higher than previously reported in the kidney, and 2.5 times higher than in the liver (Landry and

Sis, 1992; Presti et al., in press). These data provide insight into the metabolism, excretion, and long-term accumulation of mercury in sea turtles. Further investigation is warranted to study mercury accumulation found in sympatric populations of different species of sea turtles.

The current study focused on the black sea turtle, *Chelonia mydas agassizii*, near Bahia de los Angeles, Gulf of California, Mexico. This region is an important feeding area and developmental habitat for black sea turtles originating from nesting beaches of southern portions of the Eastern Tropical Pacific (Cliffton et al., 1982). This region is also adjacent to historic gold mining and mercury leaching operations, suggesting that it is a potential point source of mercury contamination. Black turtles in the Gulf of California have been found to be omnivorous, but forage primarily on red algae (Seminoff et al., 1998). Further, because there is an existing knowledge of the foraging and movement patterns of black sea turtles in this study area, we can more adequately interpret the presence or absence of mercury contamination.

Methods. — The field study site was Bahia de los Angeles on the central eastern coast of the Gulf of California, Mexico. Sea turtles were captured in entanglement nets (100 m x 8 m). Nets were continually monitored during the entire trapping period to prevent drowning mortality. Individual capture data were obtained for each turtle, including straight carapace length (SCL) and body weight. Diet analysis was performed by gastric lavage, the gentle flushing of food particles through an esophageal tube (Forbes and Limpus, 1993). Turtles were housed at the Centro Regional de Investigacíon Pesquera, Sea Turtle Research Station.

Superficial scrapings of the scutes of the carapace were obtained from both captive and wild black sea turtles. Approximately 0.1 g of tissue was removed using a plastic scraping tool and frozen for storage in a whirl-pak bag. Samples were taken from areas on the carapace that were free of algae and barnacles. Only the most superficial keratinized layer was used with no penetration to the underlying keratinaceous-bone interface.

Tissue samples were stored in Teflon vials and digested in ultra pure nitric acid, according to a protocol developed by Orvik (1997). All samples were analyzed for mercury using an automated version of the cold vapor atomic fluorescence technique described by Gill and Bruland (1990). Mercury vapor was pumped through a tube, collected on a gold trap, and measured by the fluorescence cell of the spectrophotometer. Method blanks, containing 1 g deionized water, accompanied each set of samples to monitor contamination. A certified standard reference material was also analyzed with each set of samples to maintain quality control.

Results and Discussion. — Scute scrapings were taken from 17 black sea turtles in Bahia de los Angeles, Mexico (wild $n = 13$; captive $n = 4$). The turtles ranged in size from 45.7 to 89.1 cm SCL and 13.6 to 99.5 kg body weight. Gastric lavage was performed on all turtles sampled; they were found to eat mainly algae, including *Gracillaria* spp. and *Codium* spp. Mercury was detected in scutes of 16 of 17 turtles sampled. Values ranged from 0 to 308.7 ng/g with a mean and standard deviation of 50.9 ± 78.8 (Table 1).

Table 1. Comparison of mercury levels (ng/g) in carapace scutes of two species of sea turtles.

Species	*n*	Mean	S.D.	Range
Chelonia mydas agassizii	17	50.9	78.8	0–308.7
Lepidochelys kempii	76	920.0	1036.3	41.3–7486

Mercury is a non-essential metal and, therefore, any accumulation of mercury is considered to be contamination. Since all but one of the turtles sampled had mercury in its scutes, there is evidence that this population of sea turtles has been exposed to mercury contamination. However, these levels are not considered to be relatively high and were on the average lower than levels found in carnivorous Kemp's ridley sea turtles (*Lepidochelys kempii*) in the Gulf of Mexico in a 1997 study (Presti et al., in press) (Table 1). These two species were compared due to their differences in foraging ecology; the results may be suggestive of bioaccumulation of mercury up the food chain in sea turtles.

When ridley sea turtles were divided into two size classes, there was a greater correlation between size and mercury levels in the group of larger turtles (the larger the turtle, the more mercury was found) (Presti et al., in press). However, the same correlation was not found with black sea turtles. There was a lower correlation ($r^2 = .145$) of mercury levels with size in larger turtles (SCL > 42 cm; $n = 14$) than in the smaller turtles ($r^2 = .332$) (SCL < 42 cm; $n = 2$). This may possibly be explained by examining the ecology and migration of black sea turtles in the Gulf of California. Radio and satellite tracking have shown that larger turtles migrate in and out of the Bahia de los Angeles area at a much faster rate than juvenile turtles. It has been shown that smaller turtles stay in that region for a much longer period of time to use it as a developmental feeding habitat (Seminoff et al., 1998). Due to the past gold mining history and mercury leaching operations in Bahia de los Angeles, this town may be a potential exposure site of mercury contamination, which may pose the highest risk to resident juvenile sea turtles. However, the sample size of this study was small and further investigation is needed to justify any conclusions.

Recent attention has been drawn to the increasing problem of fibropapillomatosis in green sea turtle (*Chelonia mydas*) populations. Analysis of toxicological data may prove to be important in the search for compounding environmental and immunological factors causing certain turtle populations to succumb to the effects of this disease as well as others. Such interdisciplinary studies will allow us to obtain more comprehensive knowledge of sea turtle health and to provide greater contributions for their conservation.

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