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method would be to preserve the specimen in isolation upon collection and immediately examine or filter the fixative solution for commensals.

Material Examined.—*Stenocionops spinimana*: one specimen, lower Florida Keys south of American Shoals Lighthouse, 24°29.5'N, 81°30.0'W, 84 m, J. D. Thomas, 21 July 1978; three specimens, 28°12.0'N, 79°58.4'W to 28°10.2'N, 79°58.1'W, 97 m, otter trawl, collected by L. E. Scotto and L. J. Becker, Smithsonian Institution, Ft. Pierce Marine Station, 18 September 1974, IRCZM#89: 1755. *Rochinia crassa*: one specimen, 27°24.6'N, 79°58.1'W, 187 m recolonization tray, collected by Benthic Ecology Department, Harbor Branch Foundation, Inc., 18 June 1978, IRCZM#89: 3479.

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GROWTH CURVES FOR CAPTIVE LOGGERHEAD TURTLES, *CARETTA CARETTA*, IN NORTH CAROLINA, USA

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There are no techniques presently available for aging individuals of any sea turtle species in the wild (Bustard, 1979; Márquez, 1972). Estimates of the age at maturity of loggerhead sea turtles, *Caretta caretta,* often are based on the growth rates of captive individuals and sizes of wild nesting females. However, no attempt has been made to specify growth equations in the majority of studies on captive loggerheads (Albert I, Prince of Monaco, 1898; Parker, 1926; 1929; Hildebrand and Hatsell, 1927; Caldwell et al., 1955; Caldwell, 1962; Hughes et al., 1967; Kaufmann, 1967; 1975; Stickney et al., 1973; Rebel, 1974; Witham and Futch, 1977; Schwartz, 1981). Uchida (1967) used graphical methods to fit 4.5 years of growth for two captive loggerheads to logistic equations and predicted that the turtles would reach mature sizes in 6 or 7 years. In this paper, we present growth equations for two loggerheads raised in captivity for 14 years. The conditions under which the turtles were kept and the results obtained differ substantially from those in Uchida's (1967) earlier study.

Turtles were hatched from eggs collected at Emerald Isle, North Carolina, in 1968 and incubated in styrofoam coolers. Two (designated as A and B) were retained to determine growth trajectories. From mid-March to late November, they were kept outdoors in concrete tanks 15 m long, 7.5 m wide and 0.75 m deep at Morehead City, North Carolina. Unfiltered water from Bogue Sound was

Table 1. Coefficients of determination (r^2) and asymptotic estimates of parameters *a*, *b* and *k* for non-linear regression of logistic and von Bertalanffy equations for growth in length of two loggerhead turtles (A and B) raised in captivity [one asymptotic standard error indicated in brackets]

Equation	r^2	*a*	*b*	*k*
LOGISTIC:				
A	0.9984	91.8 cm [3.65]	13.0 [1.30]	0.325 [0.021]
B	0.9944	99.2 [12.7]	12.2 [1.76]	0.264 [0.035]
VON BERTALANFFY:				
A	0.9837	1,228.0 cm [12,211.6]	0.997 [0.031]	0.00411 [0.0422]
B	0.9735	541.8 cm [3,603.1]	0.990 [0.061]	0.00810 [0.0576]

pumped through the tanks continuously. Salinities varied from 18 to 34‰ and water temperatures ranged from −1.5 to 31°C.

When water from the Sound cooled below 10°C, turtles were moved indoors, because loggerheads become stressed or die at lower temperatures (Schwartz, 1978). Indoors (from late November until mid-March) turtles were kept in circular tanks 2 m in diameter and 0.5 m deep. Incoming water was kept in a holding tank until it reached indoor ambient temperature (≅25°C), and then run into the

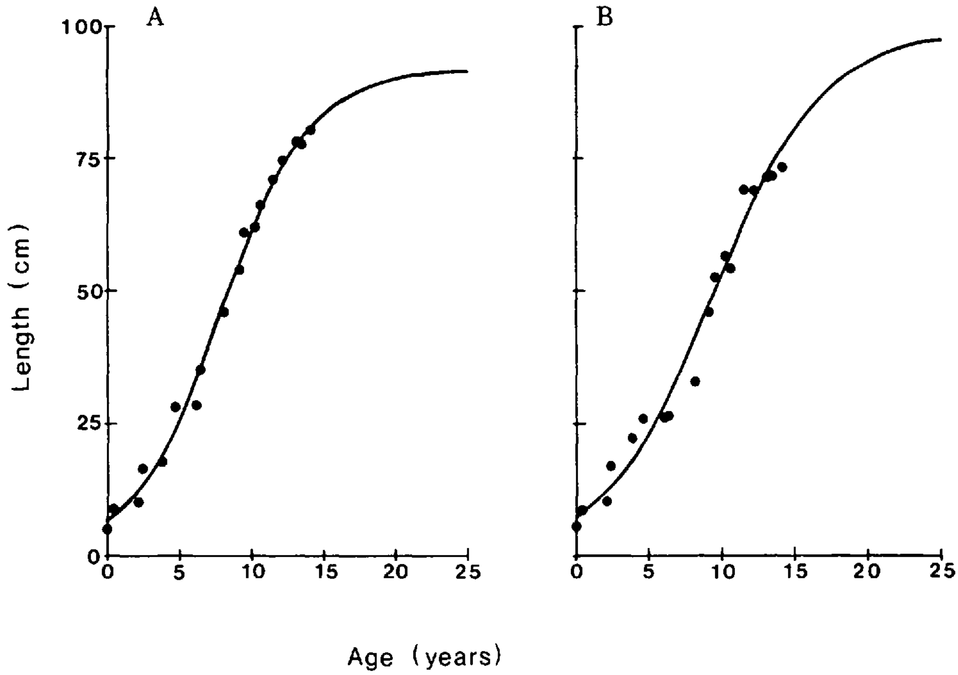

Figure 1. Predicted curves for logistic models of growth in length of two loggerhead turtles (A and B) raised in captivity. Dots represent actual measurements used to fit the equations. Turtle A: The line represents the logistic regression equation $Y = 91.8/(1 + 13.0e^{-0.325X})$. Turtle B: The line represents the logistic regression equation $Y = 99.2/(1 + 12.2e^{-0.264X})$.

tanks. The water was changed every 2 days to prevent fouling by uneaten food and excrement.

During warmer months, usually June to mid-August, turtles were fed to satiation daily. During fall and spring months, they were fed every 2 days and then every 3rd day as their activity decreased during winter. Their diet consisted primarily of fish, supplemented with squid, clams, crabs, scallops and shrimp, as available.

Straight-line carapace lengths were determined when the turtles were moved between indoor and outdoor tanks. Growth data were fit to logistic and von Bertalanffy equations using a Statistical Analysis Systems non-linear regression procedure (SAS Institute, Inc., 1979).

The logistic equation was the one used by Uchida (1967):

$$L = \frac{a}{1 + be^{-kt}},$$

where L is the length of the individual turtle (cm), a is the asymptotic value for length, b is a parameter related to the length of the turtle at birth, e is the base of the natural logarithms, k is the intrinsic rate of increase in length, and t is time (years). The von Bertalanffy equation was the one used by Fabens (1965):

$$L = a(1 - be^{-kt})$$

with parameters defined as above.

We chose to fit the logistic and von Bertalanffy equations because the logistic has been used previously to describe growth of *Caretta* (Uchida, 1967) and the von Bertalanffy equation has been used to describe the growth of Ridley turtles, *Lepidochelys* (Márquez, 1972) and hawksbill turtles, *Eretmochelys* (Witzell, 1980).

The logistic equation provides a better fit and more realistic estimates of asymptotic length for both turtles than does the von Bertalanffy (Table 1). Stoneburner (1980) reports a mean straight-line carapace length of 92.5 cm for loggerheads nesting at Cape Lookout, North Carolina, and the largest nesting female we have seen on North Carolina beaches was 130 cm long. The von Bertalanffy estimations for asymptotic lengths of 1,228.0 cm and 541.8 cm appear unrealistic, whereas the logistic estimates of 91.8 cm and 99.2 cm (Table 1) are much closer to measurements taken in the field. Growth curves for the logistic models appear in Figure 1.

Our findings support Uchida's (1967) assertion that growth of captive loggerheads fits a logistic equation better than a von Bertalanffy, although his turtles grew much faster than ours. The faster growth may be a result of Uchida's (1967) maintaining his turtles at a constant temperature of 25°C and feeding them to satiation once or twice daily. Growth rates of captive loggerheads are dependent upon the amount and quality of food provided (Stickney et al., 1973; Nuitja and Uchida, 1982). Furthermore, it has been found that captive green turtles, *Chelonia mydas*, achieve optimal growth at or above 25°C (Stickney, 1979). Thus, Uchida's (1967) estimation of a 6 to 7 year age at maturity may be based on a maximum rate of growth under almost ideal conditions. Recall also that Uchida (1967) based his estimate on only 4.5 years of observed growth, whereas our turtles were kept for 14 years.

Pritchard (1979) suggests that mature male loggerheads are about the same size as females, but exhibit a secondary sexual characteristic in having longer tails. The tail of one of our specimens (turtle A) has begun to grow rapidly during the last 3 years, increasing from 201 to 240 mm in length during 1982 alone. Thus, turtle A is assumed to be a male. Turtle B has a much shorter tail (70 mm) and is assumed to be a female.

Taking 92.5 cm as an indication of the size of a female at maturity (Stoneburner, 1980), we would expect our captive female (turtle B) to mature at 19 to 20 years old (Fig. 1). Even if 86 cm (i.e., the length of the smallest nesting female we observed in North Carolina) is taken as an indication of size at maturity, our female would not mature until 16 to 17 years old. These estimates fall between the 10 to 15 year age at maturity predicted by Mendonça (1981) and the 22 year age at maturity predicted by Frazer (1983), based on short-term growth rates observed for wild loggerheads. Even though information from captive studies should be extrapolated to wild populations with caution, such studies may provide insight about natural growth rates until more information becomes available on growth rates in the wild. Thus, conservationists who protect eggs on natural beaches may not observe any increase in the numbers of nesting females for up to 2 decades.

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