

A Growth Curve for Green Sea Turtles, *Chelonia mydas*, in the U.S. Virgin Islands, 1913-14



Nat B. Frazer; Rosamund C. Ladner

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function as macroplankton traps (Frazier et al., 1985). In this case the caloric intake per food item would be increased and the number of items required per day would be decreased.

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MOLLY LUTCAVAGE AND PETER L. LUTZ, *Department of Biology and Living Resources, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida 33149*. Accepted 28 Aug. 1985.

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A GROWTH CURVE FOR GREEN SEA TURTLES, *CHELONIA MYDAS*, IN THE U.S. VIRGIN ISLANDS, 1913–14.—Due to the paucity of information on growth rates in natural populations of green turtles, virtually any measurements arising from the capture and recapture of wild specimens are of value to conservationists and demographers. In this paper we construct a growth curve for *Chelonia* using information gathered by Schmidt (1916) in his study of the movements of juvenile green turtles in waters around the U.S. Virgin Islands (then the Danish West Indies) in 1913–14.

Fabens (1965) provided a method for rearranging the von Bertalanffy equation to allow fitting of data from animals of unknown age to estimate growth curves. The method requires measurements at capture and recapture and the time interval between measurements. It has been used previously to provide growth curves for both *Chelonia* and *Caretta* in Florida waters (Frazier and Ehrhart, 1985).

The form of the von Bertalanffy equation used by Fabens (1965) is:

$$L_t = a(1 - be^{-kt}), \quad (1)$$

where L_t is length at age t , a is asymptotic length,

b is a parameter related to size at birth, e is the base of the natural logarithms, k is a constant growth rate and t is time. Parameters a and k may be estimated by fitting measurements to a rearranged form of the equation (Fabens, 1965),

$$L_t = a - (a - L_c)e^{-kt}, \quad (2)$$

where L_t is length at recapture, L_c is length at first capture and d is the time interval between capture and recapture. Once an estimate is available for a , equation 1 can be rearranged to calculate a value for b if the size of the organism at birth (i.e., L_0) is known (Fabens, 1965).

At hatching ($t = 0$), equation 1 simplifies to:

$$L_0 = a(1 - b). \quad (3)$$

Rearranging equation 3 yields:

$$b = 1 - \frac{L_0}{a}. \quad (4)$$

We fit carapace measurements at capture and recapture and time intervals between capture and recapture of eight juvenile green turtles from Schmidt's (1916) study to equation 2 using a non-linear, least-squares regression procedure (SAS Inc., 1979) to obtain estimates of a and k . Ranges of sizes of the turtles at first capture were from 28.5–57.0 cm ($\bar{x} = 42.3$); time intervals between capture and recapture ranged from 0.29–0.92 yr ($\bar{x} = 0.57$). The regression for equation 2 resulted in estimates of $a = 121.64$ and $k = 0.075$ ($r^2 = 0.96$).

In order to estimate b with equation 4, it was necessary to have an indication of L_0 , the size of hatchling green turtles. Schmidt (1916) reported that nesting of green turtles was extremely rare in the Danish West Indies; he found neither hatchlings nor eggs. However, measurements of 54 green turtle hatchlings taken at St. Croix in 1984 indicated a mean carapace length of 5.27 cm (K. Eckert, pers. com.). Using values of $a = 121.64$ and $L_0 = 5.27$ to solve for b in equation 4 resulted in $b = 0.96$. Incorporating values for a , b and k into equation 1 provided the complete von Bertalanffy growth equation (Fig. 1):

$$L_t = 121.64(1 - 0.96e^{-0.075t}). \quad (5)$$

Equation 5 can be used to provide preliminary estimates of age at maturity for green turtles in waters of the Lesser Antilles, given some indication of size at maturity.

Although green turtles rarely nest in the Virgin Islands even today, measurements are available for four that nested on St. Croix in 1984.

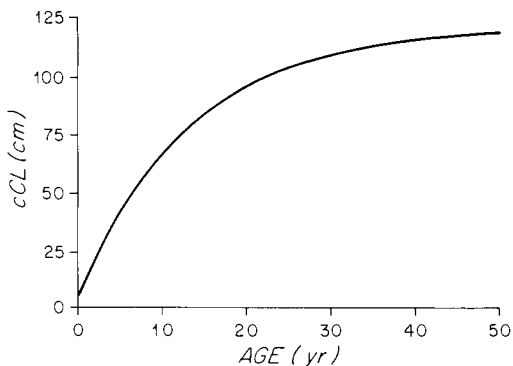


Fig. 1. Predicted curve for growth in curved carapace length (cCL) of green sea turtles, *Chelonia mydas*, in the U.S. Virgin Islands, 1913–14, based on the von Bertalanffy equation, $Y = 121.64(1 - 0.96e^{-0.075x})$.

The mean curved carapace length for these specimens was 112.75 cm; the smallest turtle was 106.75 cm long (K. Eckert, pers. com.). Because Schmidt (1916) measured turtles from the nuchal scute to the notch between the two posterior marginal scutes and Eckert measured from the nuchal scute to the tip of one of the posterior marginals, we subtracted one centimeter from Eckert's measurements.

Taking the size of the smallest adult (105.75 cm) as a lower estimate and the mean size (111.75 cm) as an upper estimate for L_t , we calculated age at maturity by incorporating the values into equation 5 and solving for t . Estimates are 27 and 33 yr. We recognize that a larger sample of adult turtles would likely differ in both minimum and mean size.

It is possible that the eight juvenile turtles that Schmidt (1916) caught might have represented hatchlings from one of the larger nesting colonies in the Caribbean or the western Atlantic. Hirth (1980) reported sizes of adult female green turtles at several major nesting colonies. Using his values for mean adult size and smallest adult size (Hirth, 1980: table 1), we also estimated ages at maturity with equation 5, under alternative assumptions that Schmidt's (1916) juvenile green turtles could have come from Ascension Island, Costa Rica, or Surinam.

Because Hirth (1980) reported straight carapace lengths and our growth curve (equation 5) was expressed in terms of curved carapace lengths, we followed his assumption of a 4 cm difference between the two types of measurements. Thus, we added 4 cm to the values Hirth (1980) reported. This resulted in the following

TABLE 1. ESTIMATED AGE AT SEXUAL MATURITY FOR WILD GREEN TURTLES, *Chelonia mydas*, AT VARIOUS LOCATIONS.

Location	Age at maturity (years)	Reference
Hawaiian Archipelago	8.7+–59.4+	Balazs, 1982
Hawaiian Archipelago	40–50	Zug and Balazs, 1985
Australia (Great Barrier Reef)	30+	Limpus and Walter, 1980
Florida	25–30	Mendonça, 1981
Florida	18–27	Frazer and Ehrhart, 1985
Bermuda	27	Burnett-Herkes et al., 1984
Mauritania	5.5	Le Toquin et al., 1980
Mexico (Gulf of California)	6	Márquez and Doi, 1973
U.S. Virgin Islands	27–33	This study*
Ascension Island	17–35	
Costa Rica	12–26	
Surinam	24–36	

* See text for further details.

estimates for the smallest and mean curved carapace lengths (cm): Ascension Island—87.8, 112.1, Costa Rica—73.2, 104.1, Surinam—101, 113. Incorporating these values into equation 5 resulted in estimates of age at maturity of 17–33 yr for the Ascension Island alternative, 12–25 yr for Costa Rica and 23–35 yr for Surinam.

Carr and Goodman (1970) found that individual green turtles apparently mature at different sizes and that they grow very slowly, if at all, after achieving maturity. Therefore, we doubt that the size of the smallest female in a given population is indicative of the mean size at maturity. We suspect that our upper estimates (based on the mean size of adult females in a given nesting colony) provide better indications of mean age at maturity in each case.

There are a number of other caveats to consider. Schmidt's (1916) sample size ($N = 8$) was small and all recapture intervals were shorter than 1 yr. Thus, our analysis may not reflect the extent of individual variation or the vagaries of seasonal growth. Furthermore, all of our estimates depend upon modern measurements of hatchling and adult sizes. We do not know whether these measurements differed 70 yr ago. However, it is unlikely that hatchling size differed much from those today, given that mean sizes reported for green turtle hatchlings worldwide presently fall between 4.6 and 5.4 cm (Hirth, 1980). Insofar as the estimate of b is concerned (equation 4), using both these extremes results in estimates of 0.96 when rounded to two decimal places. Thus, it is unlikely that the estimate of b would change substan-

tially even if hatchlings had been slightly larger or smaller in 1913.

Other investigators have estimated age at maturity for green turtles in natural populations (Table 1). Our estimates are similar to those obtained in studies in which estimates were based on actual measurements of individual growth (Balazs, 1982; Burnett-Herkes et al., 1984; Frazer and Ehrhart, 1985; Limpus and Walter, 1980; Mendonça, 1981) or on other potential indicators of growth such as annuli in long bones (Zug and Balazs, 1985). The studies in Mauritania (Le Toquin et al., 1980) and Mexico (Márquez and Doi, 1973) provided much lower estimates of age at maturity (Table 1). They were based on the assumption that peaks in size-frequency distributions of captured turtles represent distinct age classes. However, there is little or no evidence for such an assumption. In any case, we find it difficult to believe that green turtles in the wild would grow faster than those fed a diet specifically formulated to ensure high growth rates in captivity (Wood and Wood, 1980).

Captive-reared green sea turtles, *Chelonia mydas*, may reach maturity in only 8–11 yr at sizes similar to mature females in their natural populations (Witham, 1970; Wood and Wood, 1980). However, growth rates of captive reptiles may have little relevance to growth rates in natural populations (Gibbons, 1976) and the time required to attain a given size may differ between captive and wild populations.

Experiments with captive sea turtles indicate that growth rates depend upon temperature

(Márquez, 1972; Hughes, 1974), type of food (Stickney et al., 1973; Wood and Wood, 1977, 1981) and the rate of consumption (Nuitja and Uchida, 1982). Temperature and food quality affect growth rate, size and age at maturity in natural populations of freshwater turtles as well (Christy et al., 1974; Gibbons et al., 1981; Parmenter, 1978). We suspect that age at maturity varies both within and among natural populations of green turtles.

The value of our growth curve for green turtles in the U.S. Virgin Islands (Fig. 1) should increase in the next few years as additional data become available. Growth studies are presently being conducted on juvenile green turtles in waters of the U.S. Virgin Islands (R. Boulon, pers. com.). Regardless of the size chosen as indicative of maturity, the growth curve that we constructed with information gathered over 70 yr ago (Fig. 1) could provide a base-line against which to compare new growth curves that could be estimated from more recent data. Such a comparison might provide the first assessment of any long-term change in growth rates for sea turtles.

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- NAT B. FRAZER AND ROSAMUND C. LADNER, *Marine Policy Center, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543. Present Address (NBF): Department of Biology, Mercer University, Macon, Georgia 31207. Accepted 13 Sept. 1985.*

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TADPOLES AND POLLEN: OBSERVATIONS ON THE FEEDING BEHAVIOR OF *HYLA REGILLA* LARVAE.—Anuran larvae are generally non-discriminatory suspension feeders (Wassersug, 1975) that ingest bacteria, diatoms, blue-green algae, green algae, protozoa, microscopic arthropods, their own fecal pellets and a wide variety of organic and inorganic debris (Gromko et al., 1973; Hendricks, 1973; Heyer, 1973; Hillis, 1982). These materials are commonly ingested in the same relative proportions as encountered (Jenssen, 1967). Here I provide evidence for the behavioral selection of conifer pollen by *Hyla regilla* tadpoles and describe the feeding behavior associated with the exploitation of this resource.

H. regilla is one of the most abundant frogs

in western North America (Brattstrom and Warren, 1955). It is common in a wide variety of habitats from deserts to rainforests (Stebbins, 1951). Wassersug (1976) considers its larvae to be typical pond tadpoles, possessing a generalized oral morphology. There have been a number of studies of the adult stage, including their feeding habits (Johnson and Bury, 1965), but the larval stage has been largely neglected.

Study site.—Observations were made from June–Aug. 1984 at four breeding sites on the eastern slope of the Sierra Nevadas in the Sagehen Creek Drainage Basin, Nevada County, California. These locations included the Borrow Pit, an artificial pit at 2010 m; Hidden Fen, a bog with slowly moving shallow water at 2150 m; Leopold Wash, a temporary stream and associated pools at 2040 m; and Cirque Lake, a semi-permanent pond at 2520 m. Tadpole behavior was observed at these sites at irregular intervals and larvae were occasionally collected for more detailed examination. Voucher specimens were deposited in the Museum of Vertebrate Zoology (MVZ #193546–49), University of California, Berkeley.

Field observations.—Conifers produce prodigious quantities of pollen (Ho and Owens, 1974). During the summer of 1984, pollen was seen blowing in sheets across the forest, beginning in mid-June when the lodgepole pine (*Pinus contorta*) was shedding pollen. Exposed areas, including the surface of still water, were occasionally coated with a layer of pollen that persisted for many weeks. Pollen is known to be a valuable source of nutrients for a number of animals (Todd and Bretherick, 1942; Smith and Mommsen, 1984) and *Hyla* tadpoles were first seen ingesting lodgepole pine pollen on June 20 at the Borrow Pit.

In the absence of pollen, tadpoles variously swam through the water column, moved along the bottom, or rested motionless on the bottom of the pond, very rarely rising to the surface. In the presence of pollen this behavior changed. The larvae often swam just below the water's surface with the trunk oriented vertically and the tail projecting posteriorly at approximately a 45° angle to the body. A short funnel could be seen extending from the water's surface into the mouth. Water drawn into the oral cavity brought in both the surface layer and any trapped particles. Such surface feeding has been observed for other species (Belkin and Gans,