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Growth of Head-Started Kemp's Ridley Sea Turtles (*Lepidochelys kempii*) Following Release

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The Kemp's ridley sea turtle (*Lepidochelys kempii*) captive-rearing, tagging, and release experiment called "head-start" began in 1978 as part of an endangered species recovery program (Woody, 1986, 1989; Phillips, 1989; Kemp's Ridley Recovery Team, 1992). Its goal was to establish a nesting colony at the Padre Island National Seashore near Corpus Christi, Texas through imprinting of hatchlings. Rearing the turtles in captivity at the National Marine Fisheries Service (NMFS) Laboratory in Galveston, Texas also gave them an early survival advantage over their wild counterparts (Caillouet et al., 1993). However, there have been no documented nestings of head-started Kemp's ridleys, although a number of recent nestings of the species in Florida and the Carolinas have been reported (Meylan et al., 1990; Anonymous, 1992, 1994; Palmatier, 1993; Bowen et al., 1994).

This paper fits growth curves to post-release straight carapace length (SCL, in cm) vs. age (t, in yr) of head-started Kemp's ridleys released along the Texas coast, based on tag returns from the Gulf of Mexico and adjacent bays. It also estimates t at sexual maturity, under the assumption that Kemp's ridleys mature sexually at least by the time they reach 60 cm in SCL (see Pritchard, 1989).

Materials and Methods. — From 1978 through 1992, 25,676 Kemp's ridley hatchlings (averaging 1712 per year and ranging from 250 to 3080 per year), were received for the experiment. Most (15,823) of the hatchlings were provided by the National Park Service's Padre Island National Seashore, but 9669 were obtained from the nesting beach near Rancho Nuevo, Tamaulipas, Mexico and 184 from a captive-breeding experiment at the Cayman Turtle Farm Ltd., Grand Cayman, B.W.I. Hatchlings from the Padre Island National Seashore were produced from eggs obtained from Rancho Nuevo, and the breeders at Cayman Turtle Farm Ltd. were originally obtained as hatchlings from Rancho Nuevo or as yearlings from the head-start experiment. Prior to release in the Gulf of Mexico or adjacent bays, 22,608 captive-reared Kemp's ridleys of the 1978–1992 year-classes were tagged with external, Hasco style 681, Monel or Inconel, foreflipper tags (Fontaine et al., 1993). Turtles released in the year following receipt as hatchlings were considered the standard in the head-start experiment. Older turtles were also released, but they were considered atypical due to the additional habituation to captive-rearing conditions they were exposed to during extended head-starting. Standard releases along the Texas coast totaled 18,790 turtles. Of these, 18,174 (96.7%) were released into the Gulf of Mexico and 616 (3.3%) into adjacent bays. The released turtles ranged in age from 0.80 to 1.27 yr, in geometric mean SCL from 13.9 to 31.0 cm, and in geometric mean weight from 0.463 to 4.839 kg.

Tag returns came from the NMFS Sea Turtle Stranding and Salvage Network (see Schroeder, 1989) and fishermen, both commercial and recreational. Fitting of growth curves was restricted to 117 tag returns from the Gulf of Mexico or adjacent bays for turtles that had been released along the Texas coast because:

(a) most head-started Kemp's ridleys were released along the Texas coast,

(b) except for a single tag return in 1994 (Richard Byles, U.S. Fish and Wildlife Service, Albuquerque, New Mexico, pers. comm., July 1994), there has been no direct evidence that Kemp's ridleys in the Atlantic return to the Gulf of Mexico (Schmid and Ogren, 1992),

(c) except for two recent nestings on the U.S. Atlantic coast (Anonymous, 1992; Palmatier, 1993; Bowen et al., 1994), the Kemp's ridley breeding population has been confined to the Gulf of Mexico (Pritchard, 1989), and

(d) growth of head-started Kemp's ridleys in the Atlantic appears to be slower than in the Gulf (Fontaine et al., 1989). For individuals recaptured more than once, only the last of their tag returns was included in the data used to fit growth curves, so as not to give undue weight to such individuals.

Logistic, Gompertz, and von Bertalanffy growth curves were fitted to paired observations ($n = 117$) of SCL and t with the microcomputer program FISHPARM, version 3.0S (Prager et al., 1987). Because the data set contained only three points representing head-started turtles older than 5 yr

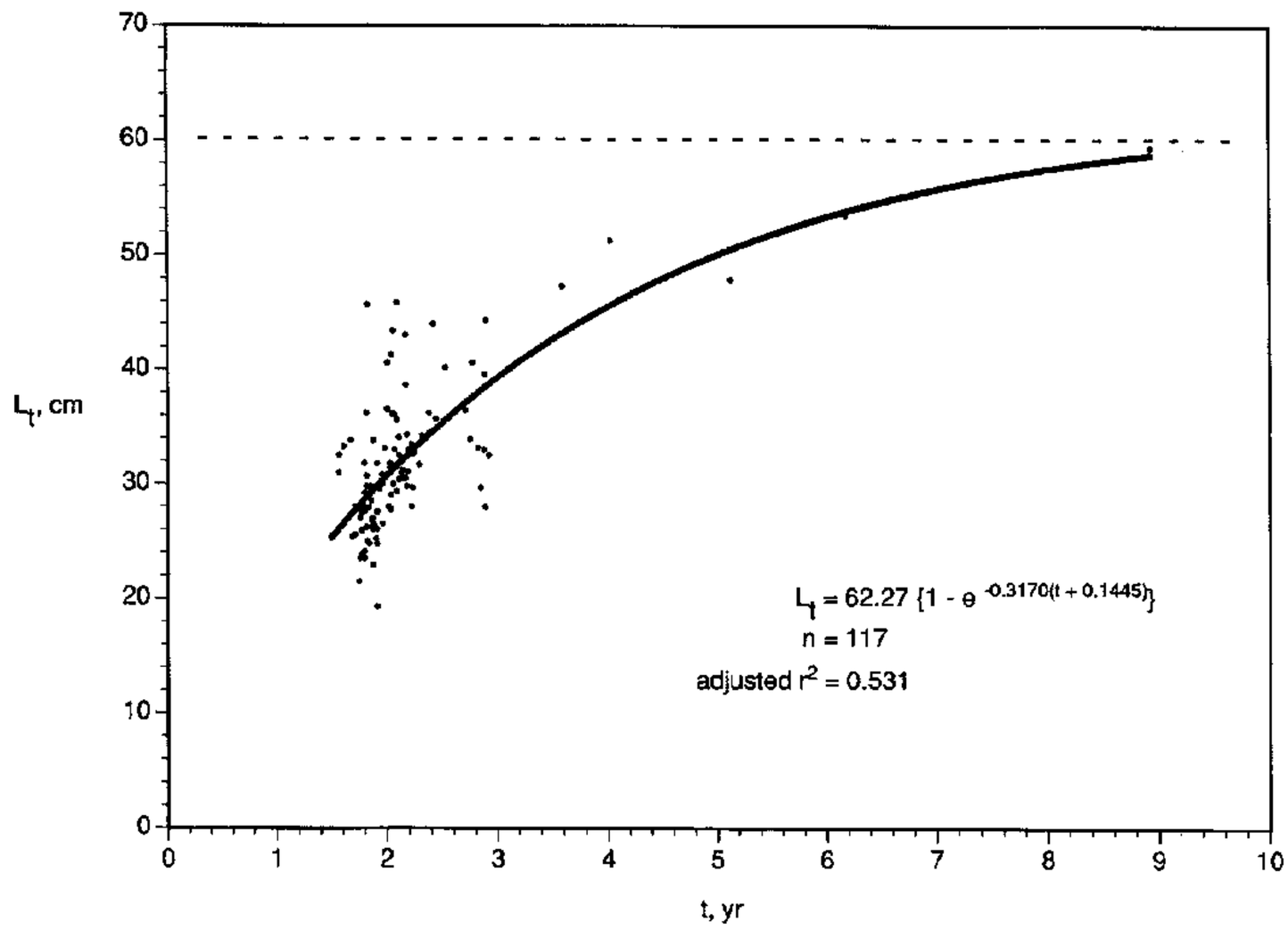

Figure 1. Plot of straight carapace length (SCL_t, cm) vs. age (t, yr) of head-started Kemp's ridley sea turtles recaptured in the Gulf of Mexico or adjacent bays after rearing in captivity and released along the Texas coast. The solid line represents a fitted von Bertalanffy growth curve, and the dashed horizontal line represents an assumed SCL_t at sexual maturity of 60 cm.

(Fig. 1), the fitted models were heavily weighted by data from younger turtles. Gender of only 5 of the 117 turtles was determined, and all 5 were females less than 3 yr old. We cannot rule out the possibility that males were included in the data set, because males as well as females were head-started (Caillouet, in press). In addition, any differences in growth and survival rates between males and females could have contributed to the variability in the data.

Results and Discussion. — The von Bertalanffy growth model fit the data slightly better (the adjusted coefficient of determination, r^2, was 0.531) than did either the Logistic or Gompertz models (r^2 was 0.528 and 0.530, respectively). The estimated asymptotic SCL was highest for the von Bertalanffy (62.27 cm), intermediate for the Gompertz (59.57 cm), and smallest for the Logistic (57.99 cm). The highest asymptotic SCL, 62.27 cm, was about 2 cm less than the mean SCL (64.6 cm) and about 13 cm less than the largest SCL (75.0 cm) of Kemp's ridley nesters at Rancho Nuevo (see Chavez et al., 1968 and Chavez, 1969).

The fitted von Bertalanffy growth equation was:

$$SCL_t = 62.27\{1 - e^{-0.3170(t + 0.1445)}\} \qquad [1]$$

The size and age at sexual maturity are unknown for Kemp's ridley. To obtain an approximation of the age at sexual maturity for head-started Kemp's ridleys, we assumed that the turtles become sexually mature at least by the time they reach 60 cm in SCL. By substituting 60 cm for SCL_t in equation 1 and solving for t, we estimated age at sexual maturity in head-started Kemp's ridleys released into the Gulf of Mexico as 10 yr.

At the Rancho Nuevo nesting beach, 203 mature Kemp's ridley females ranged in SCL from 59.5 to 75.0 cm, with a mean of 64.6 cm (Chavez et al., 1968). Chavez (1969) presented carapace lengths (probably SCL) of 285 adult female Kemp's ridleys at Rancho Nuevo, ranging from 53.5 to 75.0 cm, with a mean of 64.3 cm (see also Brongersma, 1968 and Pritchard and Márquez, 1973). At Rancho Nuevo, nesters of the same age probably exhibit a normal size-frequency distribution, with most individuals near the mean SCL and few individuals near the lower and upper extremes. However, the overall size-frequency distribution of nesters at Rancho Nuevo encompasses turtles of various ages, not just first-time nesters (see Pritchard, 1990). Sexual maturity is reached before the turtles nest for the first time, but the size difference if any between that at which sexual maturity is reached and that at which nesting takes place for the first time probably is small.

We could not use the mean SCL (64.6 or 64.3 cm) for Rancho Nuevo nesters in equation 1, because it was larger than the fitted asymptotic SCL (62.27 cm). However, the average size of nesters at Rancho Nuevo clearly does not represent the size at which Kemp's ridleys first reach sexual maturity. Thus, we used 60 cm SCL as an approximation of the size at which Kemp's ridleys first reach sexual maturity, which is close to half the distance between 53.5 cm and 64.6 cm. Zug (1990) used a similar SCL (about 59.5 cm) to estimate age at sexual maturity in Kemp's ridley (see Zug, 1990; Fig. 1). It is noteworthy that Zug's (1990) fitted Logistic, Gompertz, and von Bertalanffy growth curves for Kemp's ridley not only had asymptotic SCLs below 64.6 cm, but also below the asymptotic SCLs we estimated for these three growth curves. Therefore, 60 cm is probably not too small a SCL to use in estimating age at sexual maturity in Kemp's ridley.

Published estimates of age at sexual maturity for Kemp's ridleys range from 5.5 yr to more than 10 yr (Márquez, 1972; Márquez et al., 1982; Pritchard and Márquez, 1973; Zug and

Kalb, 1989; Zug, 1990). The estimates of more than 10 yr were based on Kemp's ridleys along the Atlantic coast of the U.S. (Zug and Kalb, 1989; Zug, 1990). The lower estimates of 5.5–9 yr were based on Kemp's ridleys from the Gulf of Mexico (Márquez, 1972; Márquez et al., 1982; Pritchard and Márquez, 1973). This is consistent with the observation that head-started Kemp's ridleys exhibited slower growth in the colder waters of the Atlantic than in the warmer waters of Gulf of Mexico (Fontaine et al., 1989).

One Kemp's ridley smaller than the smallest nester reported for Rancho Nuevo nested in captivity at Cayman Turtle Farm Inc., Grand Cayman, BWI in 1984. This 5-yr-old captive-reared Kemp's ridley had a curved carapace length (CCL) of 48.3 cm. It laid eggs which produced a few hatchlings, demonstrating that the eggs were fertilized, but the hatchlings died (Wood and Wood, 1984). Successful nesting in captive-reared Kemp's ridleys was first demonstrated at Cayman Turtle Farm Inc. in 1986 when three 7-yr-olds with 56 cm CCL produced viable hatchlings (Wood and Wood, 1988, 1989). Kemp's ridleys apparently grow faster in captivity than in the wild (see Caillouet et al., 1986; Fontaine et al., 1989), so they may reach sexual maturity at a smaller size and earlier age than wild Kemp's ridleys. It is also possible that head-started Kemp's ridleys are larger when released than are wild Kemp's ridleys of comparable age, thus shortening the time to sexual maturity in head-started animals. We consider our approximation of 10 yr to maturity to be conservative because it is based on an assumed SCL of 60 cm at sexual maturity, and a von Bertalanffy growth curve that was heavily weighted by data from turtles less than 5 yr old. However, we agree with Zug (1990) that the paucity of growth data for larger juveniles and subadults prevents reliable estimation of the age at sexual maturity for Kemp's ridleys.

The age and size at which Kemp's ridleys reach maturity are still unknown, both for wild as well as head-started turtles released into the wild. When based on fitted growth equations, the age at sexual maturity is determined by the estimated parameters of those equations as well as the choice of size at sexual maturity. The Kemp's ridley nesting beach at Rancho Nuevo has been well protected for two decades without population recovery. Assuming that such protection will continue, the rate of population recovery will depend to a large extent on actual sex ratios, survival rates, and growth rates of the turtles at sea, which will determine how soon they reach sexual maturity and how long they continue to reproduce thereafter. Therefore, it is essential that estimates of age at sexual maturity be improved so that population recovery modeling and prediction can proceed with greater accuracy and precision.

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