EARLY GROWTH AND OCEANIC SURVIVAL OF PEN-REARED SEA TURTLES[1]

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ABSTRACT: Eggs of the green turtle, *Chelonia mydas*; loggerhead turtle, *Caretta caretta*; and leatherback turtle, *Dermochelys coriacea* were gathered from Hutchinson Island, Florida, USA, during 1971 and 1972, and incubated in the laboratory. Hatchlings were pen reared at several facilities. During 1971, 61% of green turtle eggs hatched, and in 1972, 58% hatched; no data were obtained for loggerhead or leatherback turtles. Mean carapace length of 25 randomly selected green turtles was 21.4 cm and mean total weight was 1.302 kg at age 1 year. Mean carapace length of 25 randomly selected loggerhead turtles was 18.4 cm and mean total weight was 1.278 kg at age 1 year. Leatherback turtles grew rapidly on a diet of *Cassiopeia xamachana* (Cnidaria: Scyphozoa); at age 6 months, 1 leatherback turtle weighed 1.642 kg. A wide range of individual growth rates was found for each species. Short-term studies indicated no differences in growth of green turtles fed either fish only or an omnivorous diet, and that green and loggerhead turtles grew well on a diet of *C. xamachana*. Recapture of 21 tagged green turtles released from Florida suggests that hatchery reared turtles can survive in nature.

THE drastic decline of the green turtle resource in Florida and adjacent waters (Carr and Ingle, 1959; Parsons, 1962; Carr, 1967) prompted the Florida Department of Natural Resources Marine Research Laboratory to investigate methods of restocking natural populations. Success in laboratory rearing of sea turtles (Hildebrand and Hastel, 1927; Schmidt and Witham, 1961; Caldwell, 1962; Uchida, 1967; Witham, 1970; Stickney, White and Perlmutter, 1973), and a recently derived theoretical population dynamics model for green turtles (Hirth and Schaffer, 1974) indicate restocking with hatchery reared sea turtles could be feasible. Status of recent studies on the hatching and rearing of green turtles, *Chelonia mydas* (Linné), loggerhead turtles, *Caretta caretta* (Linné), and leatherback turtles, *Dermochelys coriacea* (Linné) by the Marine Research Laboratory is reported herein. Oceanic survival of tagged, pen-reared green turtles is also discussed.

MATERIALS AND METHODS

Collection and Hatching of Eggs.—Eggs were collected from natural nests on Hutchinson Island, Florida, USA, in 1971 and 1972. All eggs were collected within 24 h after being laid; previous observations had indicated that mortality is quite high if eggs are moved after embryo development has advanced beyond that point.

Eggs collected during 1971 were incubated in wooden boxes, each with a 2.5-cm diam hole in the bottom to facilitate air circulation and prevent fluid accumulation. Nests were reconstructed in as natural a manner as possible, using beach sand to line the bottom and sides and cover the eggs. During 1972, eggs were incubated in 5-gallon [= 19 litres] plastic buckets, each with several 19-mm diam holes in and near the bottom; nests were reconstructed as in wooden boxes. Local beach sand, composed mostly of finely fragmented shell material, was moistened with tap water periodically to prevent dehydration.

Facilities.—Green turtles hatched in 1971 were pen reared at: (1) House of Refuge Museum near Stuart, Florida, (2) a private oceanfront estate in Gulfstream, Florida, (3) the Miami Seaquarium, Miami, Florida, and (4) Skidaway Oceanographic Institute, Savannah, Georgia. A few loggerhead turtles were reared at House of Refuge and Skidaway. Unsuccessful attempts were made to rear leatherback turtles at House of Refuge. All Florida reared turtles were tagged and released in 1972.

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The 1972 hatch of green turtles was reared at House of Refuge, Gulfstream and Miami Seaquarium. Because of limited space at all facilities, no loggerhead turtles were intentionally retained for pen rearing, but a few were acquired from various sources. Limited success was achieved in rearing leatherback turtles at Seaquarium. All turtles were tagged and released in 1973.

All turtles were held in tanks supplied with sea water. Tank size and water exchange rates varied among facilities, but adequate space was provided and water was exchanged several times each 24 h.

Diet.—Cooked crab offal from crab processing plants was the basic diet for green and loggerhead turtles at House of Refuge and green turtles at Gulfstream. Manatee grass, *Syringodium filiforme* Kutzing in Hoenhacker, was used as a diet supplement for turtles at House of Refuge during 1971–1972; sea purslane, *Sesuvium portulacastrum* (L.) L., was used as a supplement during 1972–1973. Turtles at Gulfstream were offered a variety of garden vegetables to supplement crab scrap during both 1971–1972 and 1972–1973. Except for a short-term herbivorous diet experiment, turtles at Seaquarium were fed a diet of fish supplemented with lettuce and cabbage. Turtles at Skidaway were fed a proprietary trout food, ground fish, a mixture of half trout food and half ground fish, or ground frozen crab scrap (Stickney et al., 1973). When available, Portuguese man-of-war, *Physalia physalis* (Linne) and other cnidarian medusae were fed to turtles at House of Refuge and Gulfstream during both growing seasons. In 1971, at House of Refuge, one small group of green turtles ($N = 12$) were fed a whole fish diet, and 13 were fed a combination diet based upon crab scrap for 81 days to compare growth rates. The unsuccessful 1971 efforts to rear leatherback turtles used an omnivorous diet including fish, fish gonads, chicken liver, and several species of algae. One species of jellyfish, *Cassiopeia xamachana* Bigelow, was used for the 1972–1973 leatherback feeding study at Seaquarium.

Measurements.—Carapace length (CL), carapace width, and total weight (TW) were taken biweekly or monthly for 25 green and loggerhead turtles selected at random from House of Refuge. Previous difficulties in rearing leatherback turtles suggested that they be handled infrequently. However, some weight data were obtained for those reared during 1972–1973.

Tagging.—All pen-reared turtles were measured, weighed, and tagged prior to release. Monel self-piercing tags (National Band and Tag Co., Style No. 41005, Size No. 681) were applied to the posterior proximal margin of the right foreflipper.

Results and Discussion

During the 1971 nesting season 2,521 green turtle eggs were collected; 1,544 (61%) hatched. In 1972, 1,668 green turtle eggs were collected and 964 (58%) hatched. Hirth and Carr (1970) reported the natural hatch percentage for this species as about 60% ". . . probably because of inherent infertility factors." Insufficient numbers of loggerhead or leatherback turtle eggs were collected during either season to obtain meaningful percent hatching data.

Disease and Abnormality.—Spreading necrotic skin lesions were a serious problem at all rearing facilities during the early part of 1971–1972. Potassium permanganate dip was an effective medication for controlling lesions (Witham, 1973). However, this treatment was not applied until after the studies at Skidaway had been discontinued because of the disease problem (R. R. Stickney, personal communication).

Although kyphosis, abnormal curvature of the spine resulting in a humpback appearance, has been repeatedly mentioned in the literature (e.g., Carr, 1952), lordosis, a swayback condition (Fig. 1) has not been previously discussed. Significant numbers of young turtles at House of Refuge developed lordosis during 1971–1972, although

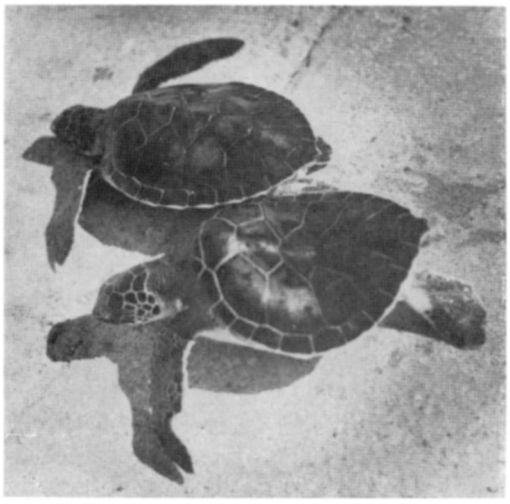

FIG. 1.—Green turtle, *Chelonia mydas*, exhibiting lordosis (foreground) and normal green turtle (background). Specimens are about 6 months old.

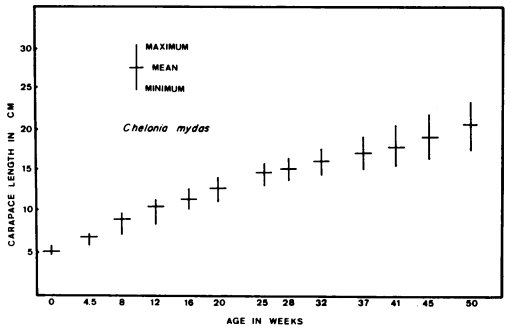

FIG. 2.—Age—carapace length relationship of 25 representative green turtles, *Chelonia mydas*, through the 1st year of life.

none exhibited this characteristic at hatching. This condition was also observed to a lesser degree at other Florida facilities. In 1972–1973, lordosis was less common at House of Refuge, and was present to a limited extent at Gulfstream and Seaquarium. Swaybacked turtles appeared to be otherwise normal and none died in captivity. Ten green turtles with lordosis were similar in weight to normal turtles of a comparable age, but CL was considerably shorter. After 50 weeks, their mean CL was 14.9 cm and their mean TW was 1.036 kg (compare with Figs. 2 and 3).

Growth.—Disease problems notwithstanding, growth rates were good at all Florida facilities. Size and weight differentials between smallest and largest turtles increased with age (Figs. 2, 3, 4, 5).

Chelonia mydas

Caldwell (1962) pen-reared 25 hatchling green turtles in northern Florida, and reported a 1st year mean CL increase of 10 cm. He did not report water temperatures, but commented that growth was limited by temperature to ". . . six warm months in which most of that growth is made in these temperate latitudes." In his opinion, turtles would grow faster if reared where water temperatures were warmer year-round. Mean CL of 25 green turtles at House of Refuge increased by 16.2 cm during 50 weeks. Growth was nearly constant throughout the year (Figs. 2, 3) and water temperatures ranged from 17.2 to 29.4°C. The extremes did not persist as long as 24 h. Green turtles ($N = 174$) at Seaquarium increased their mean CL 12.2 cm in 50 weeks. Although no water temperature data from Seaquarium are available, water was presumably warmer than at House of Refuge, some 160 km to the north. Thus, temperature alone does not appear to account for differences in growth.

Caretta caretta

Growth data for 25 loggerhead turtles are presented in Figs. 4 and 5. Comparison of the present study with that of Stickney et al. (1973) is confounded by differences in feeding regimens and duration of experiments. Hildebrand and Hastel (1927) and Uchida (1967) each reported on growth of 2 pen-reared loggerhead turtles; it is not likely that their samples were large enough to provide meaningful comparative data.

Diet—Chelonia mydas

The 12 green turtles fed a fish diet and the 13 fed a combination diet showed no

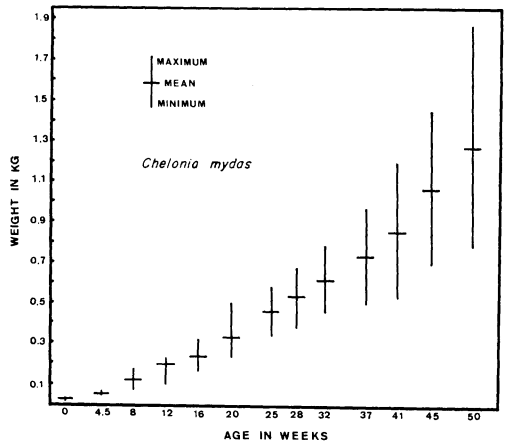

FIG. 3.—Age—total weight relationship of 25 representative green turtles, *Chelonia mydas*, through the 1st year of life.

significant difference ($P = .05$) between weight at the start of the experiment ($\bar{x} =$ 50.6 g, 51.2 g; $t = .0072$). After 81 days, mean weights of the 2 groups were 156.2 and 147.7 g, respectively. These means did not differ significantly at $P = .05$ ($t = .3870$).

Dermochelys coriacea

The omnivorous diet of leatherback turtles during 1971 was apparently unsatisfactory; all died within a short time without significant growth. Leatherback turtles fed on *Cassiopeia xamachana* during 1972–1973 grew rapidly. One attained a weight of 1.642 kg in 6 months. As with other turtle species, there was wide variation in weights. At 5 months, TW ranged from 0.476 kg to 1.232 kg. All turtles died from infections apparently unrelated to diet (Carl Chapman, DVM, Miami Seaquarium, personal communication). Young leatherback turtles may require cnidarians for survival. Brongersma (1970) has commented that, "The little information we have shows that the main food items taken by the Leathery Turtle are jellyfish and salpae." Survival and growth of leatherback turtles on a diet of cnidarian medusae suggested that other sea turtles might do

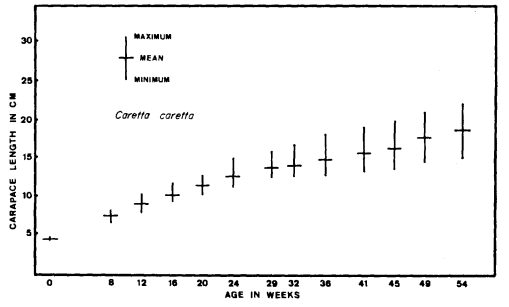

FIG. 4.—Age—carapace length relationship of 25 representative loggerhead turtles, *Caretta caretta*, through the 1st year of life.

well on a similar diet. Accordingly, a few ($N = 12$) small green and loggerhead turtles at Seaquarium were fed *C. xamachana* in a preliminary experiment. Their survival and growth on this diet suggests that cnidarians may be an important food source for hatchling sea turtles in the ocean.

Oceanic Survival.—Except for a few green turtles being retained for captive breeding studies all are released by the time they are about 1 year old. Tag returns from laboratory reared green turtles (Witham and Carr, 1968; Carr and Sweat, 1969) had suggested that they could adapt to their natural environment; returns from further releases (through 1973) provide

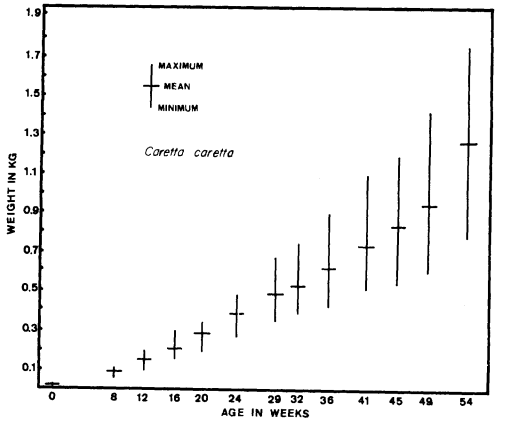

FIG. 5.—Age—total weight relationship of 25 representative loggerhead turtles, *Caretta caretta*, through the 1st year of life.

TABLE 1.—Release and capture data for green turtles, *Chelonia mydas*, tagged and released in Florida [USA] waters. Locations are approximate, and rounded to the nearest 5′ latitude and longitude.

Tag no.	Release			Capture			Map location no.
	Date	N. lat.	W. long.	Date	N. lat.	W. long.	
C 177	10 Nov '64	27°15′	80°10′	15 Jan '65	27°20′	80°10′	1
C 143	10 Nov '64	27°15′	80°10′	13 May '67	26°50′	79°00′	2
F 300	17 Oct '67	24°40′	81°15′	15 Nov '68	35°20′	75°30′	3
A 17	28 Jan '72	26°30′	80°05′	Jan '73	25°30′	76°35′	4
A 83	28 Jan '72	26°30′	80°05′	Nov '73	26°35′	77°15′	5
A 150	4 Feb '72	27°10′	80°10′	23 Aug '73	32°45′	79°55′	6
A 515	13 Apr '72	26°30′	80°04′	6 May '73	12°00′	67°25′	7
A 677	14 Apr '72	26°30′	80°05′	6 Jul '75	21°30′	71°30′	8
A 456	31 May '72	27°15′	80°10′	7 Dec '74	26°40′	77°55′	9
A 815	9 Jun '72	27°15′	80°10′	1 Nov '73	35°07′	80°00′	10
A 1003	19 Sep '72	25°40′	80°10′	1 Oct '73	36°00′	75°45′	11
A 1003	19 Sep '72	25°40′	80°10′	2 Sep '74	34°55′	76°25′	12
A 1018	19 Sep '72	25°40′	80°10′	11 Nov '73	07°05′	58°30′	13
A 1188	24 Apr '73	27°15′	80°10′	Oct '74	35°40′	76°35′	14
A 1208	25 Apr '73	27°10′	80°10′	Oct '74	34°35′	75°30′	15
A 1225	25 Apr '73	27°10′	80°10′	12 Oct '74	41°00′	72°10′	16
A 1254	16 May '73	25°40′	80°10′	14 Nov '74	35°00′	76°10′	17
A 1316	16 May '73	25°40′	80°10′	18 Jun '75	31°10′	81°15′	18
A 1414	16 May '73	25°40′	80°10′	10 Oct '74	35°55′	75°40′	19
A 1421	16 May '73	25°40′	80°10′	5 Dec '74	35°00′	76°10′	20
A 1662	6 Jun '73	28°25′	80°10′	12 Feb '75	29°50′	84°25′	21
A 1851	29 Jun '73	27°20′	80°10′	31 Jul '74	25°20′	76°55′	22

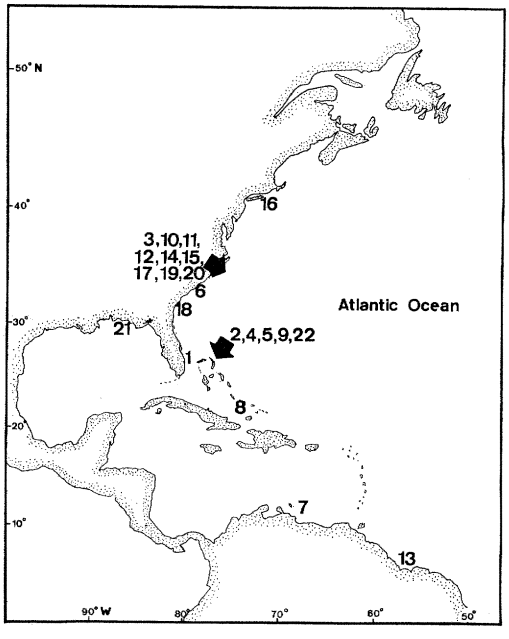

FIG. 6.—Capture locations of green turtles, *Chelonia mydas*, tagged and released by the Florida Department of Natural Resources. **Numbers refer to specific locations as shown in Table 1.**

additional evidence. Release and recapture data of all returns through the end of 1973 are shown in Table 1 and Fig. 6.

Hirth and Schaffer (1974) derived a population dynamics model for green turles showing that between 2.2 and 10 individuals per thousand female hatchlings must survive to maturity to insure population stability. Assuming a sex ratio approaching unity, survival to maturity of between 4.4 and 20 per thousand hatchlings (both sexes) would be required for population stability. Of 3106 green turtles tagged and released through 1973, 21 have been recaptured; 1 of these has been noted twice. This yields a ratio of 6.7 hatchlings: 1000 released. This is, however, a simplistic application of Hirth and Schaffer's model; it does not indicate survival to maturity. It is, nevertheless, convincing evidence that hatchery reared green turtles can survive in their natural environment.

Reproductive behavior of hatchery reared green turtles is unknown. No data are available indicating return to the re-

lease site, selection of alternate nesting areas, or failure to nest. One instance of mating of captive green turtles has been recorded (Witham, 1970).

Survival in the wild of hatchery reared yearling green turtles suggests that the harvestable supply of these valuable reptiles could be increased. Rearing facilities in each natural rookery area could release large numbers of turtles to feed and grow on the millions of hectares of available forage (Carr, 1967).

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