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Received: 5 June 1997

Reviewed: 20 April 1998

Revised and Accepted: 30 May 1998

Chelonian Conservation and Biology, 1998, 3(1):93-96
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Female-Biased Sex Ratio of Juvenile Loggerhead Sea Turtles in Georgia

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Environmentally determined sex in sea turtles has the potential of producing a skewed sex ratio if mean incubation conditions in the nesting range of the species favor production of one sex and if a differential mortality rate does not compensate for this imbalance. Dodd (1988) questioned the validity of the assumption that an even sex ratio in logger-

head (*Caretta caretta*) hatchlings from a given nesting beach could be expected in any particular year. Based on sand and nest temperatures during a 3-year study, Camhi (1993) predicted male-biased hatchling production of loggerheads on Cumberland Island, Georgia. Henwood (1987) found males predominating in the Florida adult population, as did Wibbels et al. (1987a) for juveniles in Australia, while Wibbels et al. (1987b) reported a juvenile sex ratio skewed in favor of females from Florida and Chesapeake Bay. In a later paper, Wibbels et al. (1991) reported a preponderance of females in a Florida juvenile sample. Owens (1997) summarized juvenile sex ratio data derived from testosterone assays, some confirmed by laparoscopy, and sex ratios of all Atlantic population samples favored females. Females accounted for 66% of 103 stranded juveniles and adults along the Gulf Coast of Texas (Stabenau et al., 1996). Using a 10-year sample of stranded juveniles from Cumberland Island, Georgia, we address the question of sex ratio of the United States Western North Atlantic juvenile loggerhead population.

Determining population sex ratios in wide-ranging and migratory sea turtles is difficult because adult females usually skip one to several years of nesting (Dodd, 1988) and may not migrate or forage in the same habitats as do males (Henwood, 1987). Different behaviors and mortality risks of adults might result in a modified sex ratio over time or increased likelihood of sampling error. Attempting to define the Western Atlantic loggerhead hatchling population sex ratio would entail enormous effort to include the entire nesting range with defined temporal variation in sex determination and egg survival. We propose herein that the sex ratio of the juvenile population with presumably similar habits may better define the original hatchling sex ratio, or at least the sex ratio of pelagic-stage hatchlings. After maturity, the ratio could change given unequal mortality of the sexes, but the ratio of first breeders probably reflects the juvenile ratio.

Methods. — The 27 km beach of Cumberland Island, Camden County, Georgia, USA, was surveyed at least weekly and often daily for stranded, dead sea turtles from January 1986 through December 1995. In addition, National Park Service patrols and island visitors notified us of strandings, so that we necropsied or inspected most, if not all, stranded sea turtles. Curved carapace length (CCL) was measured to the nearest 0.5 cm from nuchal notch to tip of last marginal scute. Sex was determined by inspection of gonads (Wolke and George, 1981). Juveniles were defined by their state of gonadal differentiation: for females, ovarian follicles < 2 mm diameter; for males, no expansion (width < 1.5 cm) or elaboration of testes or complete elongation of the tail. Gonads were frequently missing in very rotten and shark- or vulture-mutilated carcasses. Gut contents were removed, washed, and dried or preserved in formalin for later analyses. Departures of observed sex ratios from expected values of 1:1 were tested using standard chi-square analysis.

Results. — During this study, 459 juvenile loggerheads were necropsied, but sex could not be determined in 139

Table 1. Sex of stranded juvenile loggerhead sea turtles (*Caretta caretta*), Cumberland Island, Georgia, 1986–95.

Year	Male	Female	Undet.	Total	% Female	♂:♀ Ratio
1986	12	17	16	45	58.6	0.71
1987	15	25	15	55	62.5	0.60
1988	10	15	6	31	60.0	0.67
1989	10	13	10	33	56.5	0.77
1990	11	20	22	53	64.5	0.55
1991	6	25	9	40	80.6	0.24*
1992	15	29	16	60	65.9	0.52*
1993	7	17	10	34	70.8	0.41*
1994	16	29	16	61	64.4	0.55
1995	9	19	19	47	67.9	0.47
Total	111	209	139	459	65.3	0.53*

* = ratios significantly different from 1:1 at $\alpha = .05$

specimens (30.3%) with missing gonads (Table 1). Females predominated in all years; of 320 juveniles with sex determined, 65.3% (209) were females. Sex ratios differed significantly from 1:1 in three years and for all years combined (Table 1). Stranded juveniles were recorded from April through December, reflecting the annual regime of near-shore water temperature which allows sea turtle activity (Shoop and Kenney, 1992). Only one juvenile was recorded in December and none from January through March. The majority of specimens were recorded from May through August (Table 2). Significantly more females were recorded from April through July, and females outnumbered males in all months except October and December (Table 2). We also necropsied 53 adult loggerheads during this study, of which we determined sex in 51. Females constituted 62.5% of this adult sample.

The smallest juvenile was 42 cm CCL, and the largest was 93 cm CCL. Consequently, our samples contained juveniles of various ages and probably represented the age structure and sex ratios of juvenile loggerheads in nearby coastal Georgia waters over the course of the study. We found no correlations between size and sex, except that no juvenile females above 85 cm CCL were found, while some males were sexually immature at CCL of 93 cm (Fig. 1).

We could not discern a difference in gut contents between the sexes of the juveniles. Amounts and composi-

Table 2. Sex of stranded juvenile loggerheads (*Caretta caretta*) by month. Data pooled for years 1986–95.

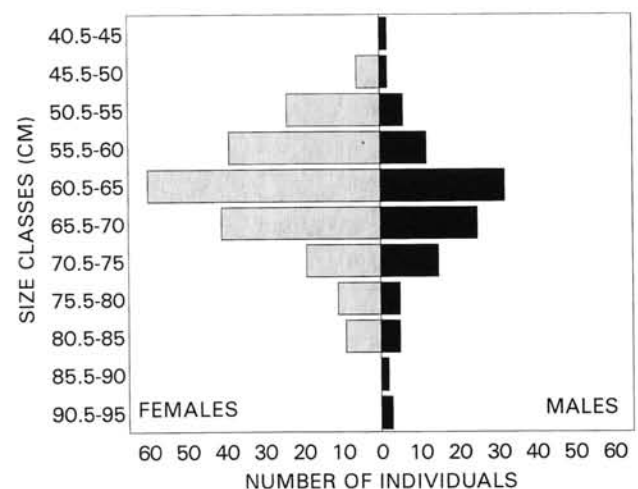
Month	Male	Female	% Female	♂:♀ Ratio
April	7	26	78.8	0.27*
May	19	43	69.4	0.44*
June	16	33	67.3	0.48*
July	27	53	66.3	0.51*
August	19	30	61.2	0.63
September	8	14	63.6	0.57
October	9	3	25.0	3.00
November	5	7	58.3	0.71
December	1	0	0.0	0.00

* = significantly different from 1:1 at $\alpha = .05$

tion varied, but standard items usually found were decapod crustaceans and gastropod mollusks along with various other invertebrates. Fishes, fish bones, and shrimp sometimes packed the entire gastrointestinal tract, and such items were judged as bycatch or trawl-net derived. Most turtles were apparently healthy prior to death judging by the amount of body fat, food in the gut, barnacle load, and superficial inspection of internal organs.

Discussion. — The assumptions underlying our observations are: 1) that juveniles of both sexes forage in the same areas in the same way, thereby equalizing the chances of being captured near shore in fishing gear, and 2) that they are equally susceptible to dying after interactions with commercial fisheries or other lethal situations. Similar gut contents in juveniles of both sexes supports the assumption of foraging in the same areas. Additionally, assuming similar physiological reactions to forced submergence seems reasonable. Given similar size at maturity, the likelihood of widely disparate age differences at maturity is slight and unlikely to have placed one sex at risk for a significantly longer period. In stranded adults from Cumberland Island, gut contents often differ between adult males, nesting females, and non-nesting females (*pers. obs.*), suggesting different feeding areas and behaviors. Henwood (1987) found seasonal differences in occurrences of adults near Cape Canaveral, Florida, with males outnumbering females during the mating season.

The annual percentage of stranded individuals whose sex could not be determined varied and was related to: 1) wind direction which moved floating, bloated carcasses seaward allowing increased time for decay and shark attack, 2) high temperatures accelerating decomposition, and 3) lack of prompt stranding notification which increased time on shore before discovery and facilitated vulture- or human-induced mutilation. While wind direction was related to stranding frequency, commercial fishing effort during warmer water temperatures also appeared correlated with numbers of strandings. Most sea turtle mortality has been attributed to shrimp trawling (National Research Council, 1990). Epperly

**Figure 1.** Size distribution and sex of 320 juvenile loggerhead sea turtles (*Caretta caretta*) stranded on Cumberland Island, Georgia, 1986–95.

et al. (1996) found that a maximum of 7 to 13% of estimated fishery-killed sea turtles actually strand on shore from November through February in North Carolina, suggesting that strandings are not necessarily indicative of turtle abundances.

Juvenile loggerheads forage and move along the entire Atlantic coast of the United States (Henwood, 1987; Shoop and Ruckdeschel, 1989; Shoop and Kenney, 1992; Morreale and Standora, 1995), and apparently move northward with warming waters of spring and southward or offshore in the cooler months. Commercial trawl fisheries may affect local and temporal distributions and migrations by providing increased food resources from discarded bycatch (Shoop and Ruckdeschel, 1982). Bowen et al. (1993) demonstrated that nesting loggerheads of the United States coast represent several genetically distinct breeding populations; consequently, juvenile loggerheads stranding on Cumberland Island probably represent a composite sample of many nesting populations. Whether the sex ratio for each nesting population varies and how each might contribute to the observed sex ratio in our samples is unknown.

Janzen (1995) showed that in the freshwater common snapping turtle (*Chelydra serpentina*) egg incubation temperatures influenced hatchling swimming speed and propensity to run, which presumably increased survivorship. Individuals from all-female or all-male producing temperatures had significantly higher survivorship during the first year of life. If the same holds true for loggerhead sea turtle hatchlings, then sex ratios at the time of emergence may differ from that of the older juveniles that we sampled.

Wibbels et al. (1991) recorded 67.9% females among 218 immature loggerheads in a power plant intake channel on Hutchinson Island, Florida. Our finding of 65.3% female juveniles on Cumberland Island, Georgia, corroborates their observation and suggests that the skewed ratio is typical of the Atlantic Coast juvenile population. Whether the skewed ratio holds for the adult population is unknown, but we found 62.7% females in a sample of adults ($n = 51$) stranded on Cumberland Island during this study. Henwood (1987) found a preponderance of adult males in Florida, but he suggested that differences in behavior of the sexes contributed to the observed 46.2% adult females, and that males

might remain in the area throughout the year while adult females resided elsewhere in non-nesting years. If non-nesting females do not return annually to the nesting area, the observed adult sex ratio should favor males. Differential mortality of adults might also be expected because of the potential increased vulnerability of nesting females.

That several studies with large sample sizes of loggerheads from different Atlantic and Gulf of Mexico localities (Table 3) found similar sex ratios (ca. 0.5♂:1♀) provides strong evidence that the skewed sex ratio is not a sampling artifact. Given the likelihood of a greater proportion of females entering the adult loggerhead sea turtle population, the ramifications on Atlantic loggerhead population dynamics and conservation efforts could be great. Future models of the loggerhead population should take the skewed sex ratio into account. Sex ratios of discrete populations of loggerheads may vary from that we observed for the composite Western Atlantic loggerhead population (Table 3).

Our observations lend support to Vogt's (1994) suggestion of manipulating the sex of hatchery-reared sea turtles to favor females, but only if the hatchling sex ratio for the local population is skewed. If Janzen's (1995) observations also apply to loggerheads, further consideration must be given to hatchery techniques. Mrosovsky and Godfrey (1994) debated the issue of manipulating sex ratios of artificially-incubated sea turtles and provided insight to other elements of the practice. Certainly, hatcheries that do not produce the sex ratio found locally may not maximize efforts to compensate for past anthropogenic mortality.

The actual adult functional sex ratio in the mating area during a given season is probably nearly equal because female loggerheads reproduce on two or more year cycles while males presumably breed annually. Henwood's (1987) observation of more males during the mating season may provide supporting data for this view. Clearly, more studies of the mating systems of loggerheads are needed to clarify the relationship of sex ratio to reproductive success. The evolutionary consequences of males potentially contributing twice the genetic information to subsequent generations (on the average) than females poses many new questions.

Acknowledgments. — We thank the many individuals and National Park Service personnel who notified us of strandings. C.K. Dodd aided in figure preparation. Comments by David Owens and anonymous reviewers provided excellent criticisms. The Georgia Department of Natural Resources and Cumberland Island Museum provided partial financial support for these studies. Permits were provided by the National Marine Fisheries Service and Georgia Department of Natural Resources.

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Table 3. Studies of sex ratios in loggerhead (*Caretta caretta*) populations of the United States and elsewhere. Data are pooled for each study. Size: J = juvenile; A = adult. Methods of sex determination include: O = observation of gonads; T = testosterone level; L = laparoscopy.

Location	Size	<i>n</i>	%♀	♂/♀	Meth.	Reference
Georgia	J	320	65.3	0.53	O	This study
Georgia	A	51	62.7	0.59	O	This study
Florida and Chesapeake Bay	J	256	66.0	0.52	T, L*	Wibbels et al., 1987b
Florida	J	218	67.9	0.47	T	Wibbels et al., 1991
Texas	J	103	66.0	0.52	O	Stabenau et al., 1996
Australia	J	87	24.1	3.14	T, L	Wibbels et al., 1987a

* 22 samples with L confirmation.

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Received: 6 August 1997

Reviewed: 21 April 1998

Revised and Accepted: 28 May 1998

Reproductive Ecology of the Indian Softshell Turtle, *Aspideretes gangeticus*, in Northern India

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The Chambal is a major river of northern India and is part of the Gangetic river basin. The river flows for about 600 km along the state boundaries of Madhya Pradesh, Rajasthan, and Uttar Pradesh. In 1983, the "Ganga Action Plan" was launched to clean the river Ganges. In this program large numbers of softshell turtles, *Aspideretes gangeticus* (Fig. 1) and *A. hurum*, were released into the river to feed upon carcasses of animals and humans which were commonly dumped into the river (Basu, 1985). Under a "Hatch and Release" program, eggs were collected from the Chambal and transported to rearing centers at Lucknow and Varanasi, where they were hatched and headstarted.

With the help of the existing facility a study was carried out on the nesting ecology of the Indian softshell turtle, *A. gangeticus*, in the Chambal river. Information on the reproductive biology of this species is sparse, including few studies on its sexual cycle (Rao and Shaad, 1985; Rao, 1986).

Study Area. — The Chambal river is perennial and flows in a northeasterly direction (Fig. 2) in northern India. A major portion of the river flows through topography characterized by ravines. The study area was located in the National Chambal Sanctuary at Etawah District in Uttar Pradesh State. It was 5.4 km in extent, reaching from 78°54' 36"E to 78°57'18"E and 26°46'36"N to 26°48'N. The river flows 102 m above sea level in this area. The river has many side channels with seasonal streams. Water level in the river fluctuated from 4 to 25 m depth and ambient temperature ranged from 4 to 47°C during the year 1992. Various softshell



Figure 1. Indian softshell turtle, *Aspideretes gangeticus*. Photo by B.C. Choudhury.