

Sex Ratio of Sea Turtles: Seasonal Changes

N. Mrosovsky*, Sally R. Hopkins-Murphy, and James I. Richardson

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Abstract. Sex ratios of hatchling loggerhead turtles *Caretta caretta* taken from South Carolina and Georgia ranged from no females in nests laid in late May to 80 percent females in those laid in early July; the sex ratio decreased to 10 percent females in nests laid in early August. These seasonal changes are consistent with the role of temperature in directing sexual differentiation in various reptiles. The data have implications for understanding the demography of sea turtles and for their conservation.

Sexual differentiation in sea turtles, as in a number of reptiles, depends on the ambient temperature during incubation of the eggs (1-3). Therefore the sex ratio of offspring should differ at different times of year. This is especially likely to happen in species of sea turtles that lay several clutches over an extended nesting season. This idea has been discussed (2, 3), but conclusive data are lacking. We now report that seasonal changes occur in the sex ratio of loggerhead turtles (*Caretta caretta*) nesting in the southeastern United States. The effects are large and have implications for conservation programs and for the study of sea turtle demography.

Hatchling loggerhead turtles were collected from 1979 to 1982 from various barrier islands in South Carolina and Georgia. The nesting beaches frequented by loggerhead turtles in these regions are predominantly primary dune, either devoid of cover or sparsely covered with

sea oats (*Uniola paniculata*). The lack of dense vegetation and the associated shade, along with the relative openness and homogeneity of the barrier island beaches, reduces the importance of spatial variables. From each clutch sampled, ten hatchlings were taken at random (4). Sex was determined histologically (5).

Sex ratio ranged from 10 percent female or less during the cooler ends of the season to 80 percent female in the middle of the summer (Fig. 1). Although variability occurred among clutches, none was less than 40 percent female between 12 June and 14 July, and most were 75 percent female or more. Not all the data came from the same year. When the results for 1982, the year with most available data, are considered separately, the seasonal trends are essentially the same. Also, some nests had been transplanted to protected sites soon after laying. However, there is no evidence that these

nests had markedly different sex ratios (Fig. 1). This is not surprising because the areas selected for reburying the eggs were similar to those selected by nesting turtles.

Because seasonal frequency of nesting is known for these beaches, the overall sex ratio for the whole season may be estimated by combining the sex ratio and nesting frequency data (Fig. 1, A and C). When all the sex ratio data are combined with the average nesting frequency data for 6 years (1977 to 1982) for Sand and South Islands, 56.3 percent of the hatchlings are female (6). When similar calculations are made from the 1982 data only, 48.2 percent of the hatchlings are female. Because relative nesting frequencies over the season were similar among the different beaches and different years, estimates of the overall sex ratio are not greatly influenced by the particular data used for nesting frequency.

Sex ratios close to equality in species whose sexual differentiation is unconstrained by sex chromosomes (7) appear to provide a new form of confirmation of Fisher's (8) theory of equal parental investment in the two sexes (9). However, some cautions are in order. First, the estimate of overall sex ratio is only an approximation because there is some uncertainty about the sex ratios during different parts of the season (Fig. 1B). Second, it is conceivable that our sample did not adequately reflect relative nesting frequencies on differently oriented

faces of dunes with subtly different thermal characteristics. Third, there are indications that on some other beaches sex ratios may be unequal (10, 11), although these data cannot be properly assessed without information on nesting frequency and sex ratio over the full season. Moreover, unequal sex ratios might be found for a particular beach because it may represent only part of a larger and thermally more diverse breeding area. If the tendency of adults to return to a particular site for nesting is weak, then the population as a whole may not be represented fairly in samples from one beach (11). More extensive work with turtle populations nesting in thermally different regions is needed to determine whether the present estimates of equality of investment in the two sexes are meaningful or just chance. Of course, the sex ratios of juveniles or adults might differ from those given for hatchlings; differential mortality during different parts of the season could result in skewed sex ratios.

We present conclusive evidence of seasonal trends that will have to be taken into account in any tests of Fisher's (8) theory. Similar investigations could also be made in areas where turtles nest year round. It has been suggested that two different turtle populations nest at some of these locations (12). Study of year-round changes in sex ratio could be used to validate these speculations (2).

Our findings also have implications for turtle management and conservation.

For instance, it has been proposed that, if eggs are harvested, they should be taken early in the season because of the greater chance that some of the early nests will be destroyed by turtles nesting later (13). Such selective harvest of early nests could distort sex ratios. Also, the practice of starting nest protection projects only when turtles are nesting in reasonable numbers, although economic in terms of manpower, might affect sex ratios in the long run. Finally, these data should be taken into account in attempts to solve problems in turtle demography with the use of "living tags" [transplanting slivers of pale plastron tissue to the darker carapace (14)]. More tag returns are likely if females are tagged. That means tagging hatchlings from eggs laid in the middle of the season.

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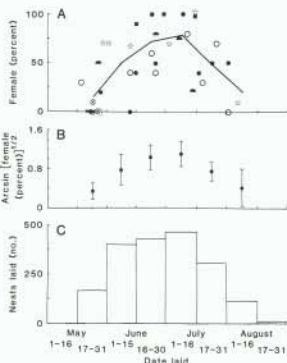
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References and Notes

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2. N. Mrosovsky and C. L. Yntema, *Biol. Conserv.* 18, 271 (1980).
3. J. D. Miller and C. J. Limpus, in *Melbourne Herpetological Symposium*, C. B. Banks and A. A. Martin, Eds. (Zoological Board of Victoria, Parkville, Victoria, Australia, 1981), pp. 66-73; F. J. Schwartz, C. Peterson, H. Passingham, A. S. B. (Assoc. Southeast. Biol.) Bull. 27, 61 (1980).
4. Nests were surrounded with wire nets, and the hatchlings were left for several hours after emergence within these nets. During this time hatchlings became mixed as a result of their natural activity. As an additional precaution animals were taken from various parts of the mass of hatchlings. The selection of nests for sampling was dictated in part by logistics, survivorship of marked nests, and availability of material from other investigators. From two of the nests, samples of eight and nine eggs only were taken.
5. C. L. Yntema and N. Mrosovsky, *Herpetologica* 36, 33 (1980); no intersexual individualism were found in our study.
6. When estimating the sex ratio at hatching from our data, survival of the eggs must be assumed to be similar over the season. A theoretically more interesting time to know the sex ratio is at the point when parental investment ends; any differential mortality occurring later is not important in our study.
7. J. W. Bukham, K. A. Bjorndal, M. W. Haiduk, W. E. Rainey, *Copeia* 3, 540 (1980).
8. R. A. Fisher, *The Genetical Theory of Natural Selection* (Clarendon, Oxford, 1930).
9. Since sexual differentiation is determined by the temperature prevailing during a critical period in the middle third of incubation [C. L. Yntema and N. Mrosovsky, *Copeia* 3, 540 (1980); (1982)], that is, after the female has returned to the sea and parental investment has ended [N. Mrosovsky, *Am. Zool.* 20, 331 (1980)], the cost of producing a female male offspring is assumed to be the same. This may not be strictly

Fig. 1. (A) Percent female of samples (ten hatchlings) from clutches laid on beaches in South Carolina and Georgia. The line shows the mean for clutches laid in each half-month of the nesting season. Solid symbols are for clutches left in situ: (■) Sand Island, South Carolina, 1979; (■) South Island, South Carolina, 1980; (●) South Island, South Carolina, 1982; (▲) Kiawah Island, South Carolina, 1982. Symbols with open centers are for reburying clutches: (○) Fripp Island, South Carolina, 1979; (○) Ossabaw Island, South Carolina, 1979; (△) Little Cumberland Island, Georgia, 1979; (○) Little Cumberland Island, Georgia, 1980; (○) South Island, South Carolina, 1982. (B) Means \pm 2 standard errors (in radians) for clutches laid in each half-month of the nesting season. A standard arcsin transformation was used because percentages were not normally distributed. (C) Nesting frequency for Sand and South Islands combined for 1977 through 1983.



- true; it might cost more for turtles to lay at certain times of the year or to climb higher on the beach into a shady area. However, with similar egg sizes it is reasonable to assume that the costs of producing a male or female are close.
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