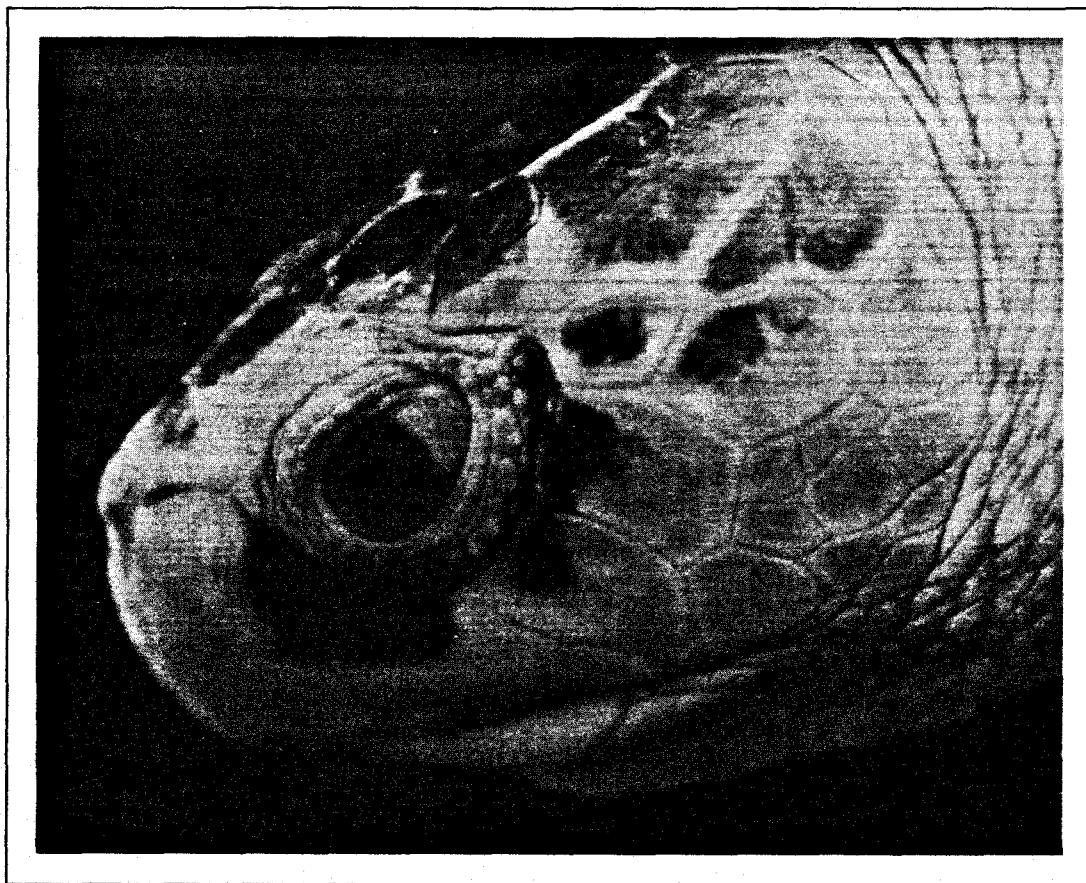


Proceedings of the First International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management



Marine Biology

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Predicted Sex Ratios From the International Kemp's Ridley Sea Turtle Head Start Research Project

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*Sex ratios were determined for groups of turtles from six year-classes of Kemp's ridley sea turtles (*Lepidochelys kempi*) from the joint U.S.-Mexico Kemp's Ridley Sea Turtle Head Start Research Project. Gonadal histology, necropsy, laparoscopy, tail length evaluation and serum testosterone assays were used to determine sex.*

Turtles examined from the 1982 (n=92, 2.9M:1F) and 1984 (n=159, 2.5M:1F) year-classes were significantly male-dominated. The turtles examined from the 1978 (n=32, 1.9M:1F) and 1979 (n=22, 1.4M:1F) year-classes also were male-dominated, but not significantly so. Those examined from the 1983 (n=12, 1M:1F) year-class had equal representation of the sexes, and those from the 1981 (n=4, 0M:1F) year-class were all females. Data from the 1984 year-class also indicated that sex ratios of clutches from a given year-class can differ significantly from one another.

The significantly male-dominated groups of turtles from the 1982 and 1984 year-classes and the significant differences in sex ratios among clutches of the 1984 year-class are consistent with the hypothesis that the sex of Kemp's ridleys is determined environmentally. Because the number of turtles examined from most year-classes was small, our interpretations should be considered with caution. Conservatively, we concluded that relatively large numbers of both male and female Kemp's ridleys have been produced by the project in the past. However, a significant masculinization was evident in two of the year-classes. The implications of male-dominance in Kemp's ridley sex ratios are discussed.

All sea turtle species tested so far have been shown to possess environmentally dependent sex differentiation systems (Yntema and Mrosovsky, 1980, 1982; Miller and Limpus, 1981; McCoy, Vogt and Censky, 1983; Mrosovsky, Dutton and Whitmore, 1984). This fact has serious implications for present-day conservation programs incorporating artificial incubation under which biasing of sex ratios is possible (Mrosovsky and Yntema, 1980; Morreale et al., 1982; Mrosovsky, 1983; Dutton, Whitmore and Mrosovsky, 1985).

Some sea turtle conservation programs use artificial incubation followed by short-term captive rearing and release of the turtles. Captive rearing is employed to reduce high natural mortality that occurs during the first year of life. The assumption is that the percentage of hatchlings surviving to reach sexual maturity could be increased by such programs. If short-term captive rearing proves to be an effective management technique, then artificial incubation of eggs in such cases could have a much greater effect on population sex ratios than when used in programs that release hatchlings immediately into the wild.

Kemp's ridley sea turtle (*Lepidochelys kempi*) is the most endangered species of sea turtle. Its current conservation program includes the Kemp's Ridley Sea Turtle Head Start Research Project that uses artificial incubation of eggs followed by captive rearing of the turtles for approximately one year (Klima and McVey, 1982). Head started Kemp's ridley sex ratios have a probability of being impacted by artificial incubation. The experimental head start project also involves imprinting in hopes of establishing a new nesting colony of Kemp's ridley on the Padre Island National Seashore near Corpus Christi, Tex.

Kemp's ridley apparently possesses environmentally dependent sex determination (Wibbels et al., 1985; Shaver et al., 1988). Therefore, the consequences of artificial incubation on Kemp's ridley sex ratios produced in the head start project require evaluation. The purpose of this paper is to review and evaluate sex ratio data from six year-classes (1978-1979 and 1981-1984) of Kemp's ridleys.

Sexing Techniques

Various techniques have been used by researchers to sex Kemp's ridley. Histological examination of hatchling and posthatchling gonads (as described by Yntema and Mrosovsky, 1980) was shown to be definitive in sexing Kemp's ridleys that died after hatching or during head starting (Wibbels et al., 1985). Direct observation of the gonads during

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necropsy has been used to sex postyearling turtles (Wood, 1982). A testosterone sexing technique described by Owens *et al.* (1978) was used to predict sex of living Kemp's ridleys that were at least two years old (Wibbels *et al.*, 1985; Y. A. Morris and D. W. Owens, personal communication). The predicted sexes of 19 out of 55 turtles sexed by the testosterone method were verified via necropsy (in those that died), laparoscopy (described by Wood *et al.*, 1983) or by tail length evaluation (Y.A. Morris and D.W. Owens, personal communication).

Results and Discussion

A summary of sex ratio data pertaining to the 1978-1979 and 1981-1984 year-classes of head started Kemp's ridleys is shown in Table 1. Data from the 1984 year-class supported the most comprehensive examination of a Kemp's ridley year-class to date, with 10 turtles sexed from each of 14 clutches, and from one to eight turtles sexed from each of the remaining five clutches. The aggregate sex ratio ($n=159$, 2.5M:1F) for the 1984 year-class samples was significantly male-dominated ($P<0.05$). If this sex ratio is representative of the entire 1984 year-class, it would seem that eggs from the 1984 year-class were incubated slightly below the pivotal temperature (i.e., that temperature that would produce a 1M:1F sex ratio; see Shaver *et al.*, 1988). Sex ratios of samples of turtles from 19 clutches of the 1984 year-class, are listed in Table 2. A Chi-square comparison among the sex ratios of the 14 clutches from which 10 turtles were sexed indicated that they were heterogeneous (i.e., sex ratios differed significantly at $P<0.05$). Such results could have derived from different incubation temperatures among the clutches. Sex ratio differences among clutches and the significant male-dominance of the aggregate sex ratio for the 1984 year-class are consistent with the hypothesis that Kemp's ridley possesses an environmentally dependent sex determination system. Furthermore, these results emphasize that sex ratios vary significantly among clutches of a year-class, so an aggregate sex ratio based on combined clutches would not be representative of all clutches of a year-class, and the particular choice of clutches in the aggregate could influence the sex ratio of the year-class as a whole.

One also must be concerned about adequacy of sample size within the chosen clutches in evaluating sex ratios and their relation to incubation temperature. Samples from the 1978, 1979, 1981 and 1983 year-classes (Table 1) are not adequate for all clutches in those year-classes. Conservatively, results for those samples suggest that relatively large numbers of both males and females were produced within those year-classes and that there was variation in incubation temperature among clutches within the year-classes.

Though 92 turtles of the 1982 year-class were sexed, all clutches were not represented. Those that were represented had only a few sexed individuals ($n<5$, Wibbels *et al.*, 1985). Furthermore, of the six clutches represented by the largest samples ($5\leq n\leq 11$), four contained only males (1M:0F) and one was male-dominated (4M:1F). This further exemplifies the problem associated with aggregating sex frequency data from various clutches when sample sizes for each clutch are inadequate. Therefore, the lack of samples from some clutches combined with insufficient sampling of others, and the male-dominance of clutches represented by the largest samples, make it difficult if not impossible to estimate with accuracy the sex ratio of the year-class. Nevertheless, these data suggest that relatively large numbers of both males and females were produced in the 1982 year-class. Assuming that a differential mortality between the sexes is not present, the significant ($P<0.05$) male-dominance of the 1982 year-class is noteworthy.

A significant male-dominance in head started Kemp's ridleys was indicated in the 1984 year-class and possibly in the 1982 year-class. This suggests that incubation temperatures were below the pivotal temperature for the species. Sex ratio data from other year-classes were inconclusive.

What should be the targeted sex ratio for the head start project, assuming that sex ratios can be manipulated by controlling environmental temperature during incubation? One strategy might be to duplicate the sex ratio in the natural population of Kemp's ridley. However, the natural sex ratio is unknown. Furthermore, the drastic decline in the Kemp's ridley population during the last four decades may have distorted the natural sex ratio, or the sex ratio may now be unstable. In addition, if the head start project succeeds in establishing a new breeding population that nests on Padre Island, the sex ratio for that population may differ from that of the population nesting in Mexico.

It might be possible to predict the sex ratio for the new population based on known characteristics of the Padre Island nesting beach, given that the pivotal temperature for sex determination in Kemp's ridley is around 30° C (Shaver *et al.*, 1988). Regardless, even if a temporally stable sex ratio could be predicted for the hypothetical population of Kemp's ridleys nesting at Padre Island and it was similar to that for Rancho Nuevo, such sex ratios may not be the ones that would maximize reproductive success within either of the two populations. In that case, a preferred strategy might be to manipulate sex ratio of head started Kemp's ridley in such a way that would enhance reproductive success.

Unfortunately, the relationship between sex ratio and reproductive success has not been studied in any sea turtle species. For that reason, the best strategy might be to hypothesize optimal sex ratios based on our current knowledge of reproductive ecology of sea turtles and status of Kemp's ridley in the wild. Sex ratios of naturally occurring Kemp's ridley have not been studied, but those of other sea turtle species have recently received attention. Standora and

Table 1. Sex ratios of head started Kemp's ridley sea turtles by year-class.

Year-class	Sex determination method	Sample size, n	Sex ratio	Chi square	Reference
1978	Testosterone*	32	1.9M:1F	3.1250	Morris <i>et al.</i> (per. com.)
1979	Necropsy	22	1.4M:1F	0.7272	Wood (1983)
1981	Histology	4	0M:1F	4.0000*	Wibbels <i>et al.</i> (1985)
1982	Testosterone	22	1.7M:1F	1.6364	"
1982	Histology	70	2.9M:1F	16.5142*	"
1983	Histology	12	1M:1F	0.0000	"
1984	Histology	159	2.5M:1F	29.9434*	"

* Sex predicted from testosterone titer was compared to known sex as determined through laparoscopy, gonad histology, or tail length for 19 of the 55 turtles from the 1978 and 1982 year-classes. All 19 of the predicted sexes were in agreement with the known sexes.

*Indicates significant difference from a 1M:1F sex ratio at $P < 0.05$.

Table 2. Sex ratios of Kemp's ridley sea turtles of the 1984 year-class that died during head starting, by clutch.

Clutch*	Sample size, n	Sex ratio
512	10	0.4M:1F
513	10	1.5M:1F
514	10	2.3M:1F
515	10	0.4M:1F
765	4	3M:1F
766	10	4M:1F
767	10	1M:0F
768	8	1M:1F
769	10	2.3M:1F
770	10	1M:0F
771	10	2.3M:1F
772	10	1M:0F
773	2	1M:0F
774	4	1M:1F
775	10	1M:0F
776	10	2.3M:1F
797	10	9M:1F
798	10	1M:1F
799	1	1M:0F
Combined	159	2.5M:1F

*Clutch identification codes used at Rancho Nuevo, Tamaulipas, Mexico.

Spotila (1985) estimated that 71 percent of the hatchling green turtles (*Chelonia mydas*) produced at Tortuguero are female. Mrosovsky, Hopkins and Richardson (1984) estimated that the sex ratio of hatchling loggerheads (*Caretta caretta*) produced on several beaches in Georgia and North Carolina was close to 1M:1F. Mrosovsky, Dutton and Whitmore (1984) estimated hatchling sex ratios of green turtles and leatherback turtles (*Dermochelys coriacea*) from a beach in Suriname to be 0.9M:1F and 1M:1F, respectively.

Sex ratios have also been estimated for the subadult and adult portion of sea turtle populations. Limpus (1985) has found a significant male dominance in resident loggerheads on Heron Atoll on the Great Barrier Reef. Wibbels *et al.* (1987) found a significant female dominance in sex ratios of subadult loggerheads captured along the Atlantic coast of the U.S.

Studies mentioned above represent initial attempts at estimating sea turtle sex ratios in nature and are far from conclusive. They suggest that sex ratio varies widely (including both significant male or female dominances) in natural sea turtle populations. Thus, it would not be unreasonable to expect that male-dominated sex ratios could occur in natural populations of Kemp's ridley. Nevertheless, there is no reason to believe that male dominance of sex ratios would enhance reproductive success of Kemp's ridley or any other sea turtle species.

Female Kemp's ridleys are known to be annual and multiannual in their reproductive cycles (Pritchard and Márquez, 1973), but the reproductive cycle of males is not known. If males are primarily annual breeders and if only one male is required to fertilize one or more females, then sex ratios dominated by males or with equal numbers of males and females may represent surpluses of males. If this is true, the total egg production of the population might be increased by shifting the sex ratio toward more females. Obviously, a better understanding of reproductive ecology of both male and female Kemp's ridley is needed to determine the validity of this hypothesis. Until such information is available, a conservative approach might be to produce a 1M:1F sex ratio in head started Kemp's ridleys, thereby preventing departures from 1M:1F that might decrease reproductive success within the population. A 1M:1F sex ratio also would be consistent with that expected from classic theory on sex allocation (Fisher, 1930), assuming that species with environmentally dependent sex determination conform to classic theory.

We also offer the more controversial opinion that production of female-dominated sex ratios might be advantageous for several reasons. Any new population established by the head start project that nests on Padre Island probably would be composed predominantly if not totally of turtles from the project. Data reviewed in this paper indicate male-dominated sex ratios in the 1984 and possibly the 1982 year-classes. Therefore, temporary production of female-dominated sex ratios might compensate the imbalance created by past male-dominated sex ratios. Even if head started turtles nest on a natural nesting beach such as that at Rancho Nuevo, instead of Padre Island, a female-dominated sex ratio also could compensate for the possibly higher mortality experienced by adult females in the past due to their greater vulnerability to natural predators and to man when nesting. Finally, regardless of where head started females nest, if Kemp's ridley reproduction is female-limited, an increase in number of females in the population should directly increase total egg production.

Given the various considerations above, we suggest that it may be advantageous to increase incubation temperatures slightly for future year-classes of Kemp's ridley eggs, assuming a pivotal temperature of 30° C (Shaver *et al.*, 1988) as a guide. The amount of increase in incubation temperature needed could be based on the specific sex ratio desired as extrapolated from available sex ratio data (*ibid.*).

In closing, we hope this discussion with its focus on currently unanswered questions shows how critically important it is to continue and intensify studies on effects of incubation temperature on sex ratio in Kemp's ridley.

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