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AN ESTIMATE OF NESTING FEMALE LOGGERHEAD TURTLES ON THE SOUTH ATLANTIC COAST OF THE UNITED STATES IN 1980

by

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Executive Summary

- An estimate of the number of female loggerhead turtles nesting in the southeast U.S. (North Carolina, South Carolina, Georgia and the east coast of Florida) in 1980 was made using aerial and ground survey data from a variety of sources.
- The estimate derived was 18,297 turtles with a standard error of 6516
- Approximate 95% confidence interval for the estimate is $(5265 < \hat{X} < 31329)$.
- The available data, however, are not sufficient to yield unbiased estimates or estimates of the possible bias.

INTRODUCTION

The loggerhead sea turtle (Caretta caretta) is currently listed as a threatened species under the Endangered Species Act of 1973. As such there is considerable interest in the numbers of loggerhead turtles that presently exist in relation to previous years. Little quantitative sampling has been done on sea turtles in their pelagic environment. Therefore, the geographical range of loggerhead species and/or breeding stocks of loggerheads cannot be well defined. Most information that is known about loggerhead turtles is derived from nesting females.

An estimate of the number of adult females which nest in a given area and year can be used to index temporal population abundance to discover time trends and in some cases, to formulate management advice. Annual surveys of nesting beaches (aerial and ground truthing) provide data for such estimates. This study gives the analyses of available survey data which lead to estimation of the number of nesting female loggerheads in 1980 on the coasts of Florida (east coast), Georgia, South Carolina and North Carolina.

METHODS

The number of nesting turtles are extrapolated from an estimate of the number of nests. The data from which the number of nests are estimated fall into three categories 1) aerial surveys of beach nesting areas; 2) ground truthing surveys of beaches in conjunction with the aerial surveys; and 3) independent ground surveys of nesting areas.

The movement of a female turtle from the water to the nesting area leaves tracks or crawls and these crawls can be counted as indicators of nesting activity. However, crawls may be classified as fresh or old depending upon whether the turtle emerged during the 24 hours of sampling or not. Also, fresh crawls are classified as true or false. True crawls are those which result in a completed nest. False crawls are the result of an emerging female which returns to the water without nesting. Both aerial and ground surveys record the number of true, false, fresh and old crawls. However, some data are biased in their classification; hence, the need for ground truthing.

The estimation procedure which was used will be outlined as follows. The statistical justification for this choice of method will be discussed in the context of the analytical results:

i) aerial survey data is used to provide an estimate of the number of new crawls per day in a sampling area; this is expanded by the number of nesting days in a sample strata to provide a biased estimate of the number of new crawls;

ii) ground truthing data is used to correct the bias in counting aerial survey crawls by including old crawls. Aerial survey crawls are multiplied by the ratio of ground truth crawls to aerial survey crawls yielding the estimate of total crawls;

iii) the all ground survey data pooled provide an estimate of the ratio of loggerhead nests to total turtle crawls; the product of the ratio and number of crawls is the number of loggerhead nests;

iv) the number of nests per female per year is derived from other studies (cited herein); this is divided into the number of nests to generate the number of nesting females.

The above formulation implies several logical assumptions which should be stated explicitly: (1) it is assumed that females which nested on the South Atlantic coast during 1980 did not nest anywhere else other than the South Atlantic coast during the 1980 season; (2) the frequency of nesting per female is constant throughout the South Atlantic coast; and (3) the ratio of aerial crawls to ground truth crawls and the ratio of loggerhead nests to ground truth crawls are constant throughout the nesting season within a sampling area. Other assumptions, tests of their verification, and deviations from the above estimation procedure will be presented in the results.

RESULTS

The results of the analysis and discussion of this analysis are presented separately by state.

Florida's East Coast

Huff, Witham, Gray and Fallon (1980) summarize ground survey results in Florida during the 1980 nesting season. These surveys were done by different organizations with varying levels of scientific expertise. Since the searching effort from these data could not be quantified, an estimate of the number of nests was not computed directly from these. Additionally, the ground surveys did not survey the entire east coast of Florida. However, this report did provide the most comprehensive source of data for estimating the ratio of the number of loggerhead nests to turtle crawls. Therefore, I used Huff, et al's data for the east coast of Florida for this purpose (excluding sampling areas at Lantana, Jupiter Island, and Fort Matanzas because the number of false crawls at these areas was not recorded). The resulting ratio was:

$$\frac{CC}{crawl} = \frac{\text{loggerhead nests}}{\text{total crawls}} = 0.5939$$

standard error = 0.0214

(Note CC is abbreviation for *Caretta caretta*).

Ehrhart (1980) and Richardson, Williamson and Groves (1980) reported on ground truthing surveys for northeast Florida and Georgia, respectively. Their data showed

	CC/Crawl	Std Error	# Crawls
NE Florida	0.5492	0.3437	244
Georgia	0.4609	0.2119	115

The ground truth ratios are not statistically different between Florida and Georgia or between ground truth and independent ground surveys. Therefore, the pooled data for all ground surveys was used for this ratio for Florida and all other states. That resulting ratio was

$$\frac{CC}{Crawl} = 0.5921$$

Standard Error = 0.0202

(Statistical derivations are weighted by number of crawls)

Ehrhart (1980) reports on aerial survey ground truthing results for eight flights on Florida's east coast. His results show that aerial survey data provide biased results of the total number of fresh crawls, the number of fresh nesting crawls and the number of fresh false crawls. However, the bias was relatively more consistent when comparing total fresh crawls from ground truth surveys to that of the aerial surveys. The ratio of ground truth survey (GS) crawls to aerial survey (AS) crawls, for 244 ground truth crawls was:

$$\frac{GS}{AS} = 0.8275$$

Standard Error = 0.2193

(Statistical derivations are weighted by the number of ground truth crawls). As can be seen by the standard error, this ratio is very imprecise. Richardson <u>et al</u>. (1980) reported similar studies for Georgia (115 ground truth crawls). The weighted statistics were:

$$\frac{GS}{AS} = 0.9487$$

Standard Error = 0.4401

Once again, these results are imprecise and are not distinguishable between states. Therefore, data were pooled and used to correct this type of bias for aerial survey data from all states. The resulting estimates were:

$$\frac{GS}{AS} = 0.8428$$

Standard Error = 0.0622

Ehrhart (1980) gave the results of his aerial surveys by flight for the entire coast of northeast Florida from the Georgia border to Port Canaveral. Additionally, Fritts (personal communication) surveyed the southeast Florida coast from Port Canaveral to Tavernier Creek (south of Key Biscayne). The results of these flights were:

Date	NE Florida # Fresh Crawls	Date	SE Florida # Fresh Crawls
5/31	71, 67 (69)	6/1	245
6/4	105, 82 (93.5)	6/15	552
6/30	137, 115 (126)	7/2	747
7/13	94	7/14	966
7/29	34	7/30	423
8/12	21	8/13	28
8/30	1	8/28	35

Note that the first three flights in NE Florida had replicate flights (returning flights). The mean of these two counts (in parentheses) was used as the crawl per day rate. Also, these three replicates provided an approximation to the variance within a single day's count. The coefficient of variation (the ratio of the standard error to the estimate, itself) averages to 0.1168 for replicates. Thus, we can expect the standard error of any single day's count to be 11.68 percent of the number counted.

The aerial crawl counts show a definite peaking in counts during early July. Therefore, the data indicated there should be stratification within the nesting season. Time strata were chosen to be of approximately equal interval length except for the ending and beginning intervals. The time strata used (along with aerial count data) are as follows:

Time Stratum	Dates	# Days	# Aerial Crawls/Day NE Florida	# Aerial Crawls/Day SE Florida
1	May 1-June 7	38	69	245
2	June 8-July 22	15	93.5	552
3	June 23-July 7	15	126	747
4	July 8-July 21	14	94	966
5	July 22-Aug 5	15	34	423
6	Aug 6-Aug 20	15	21	28
7	Aug 21-Sept 7	18	1	35

May 1 and September 7 were chosen as the first and last days of the Florida nesting season, respectively, because these are the earliest and latest recordings of nestings in 1980 from the summary report of Huff, et al. (1980). This stratification scheme has the advantage of accounting for real crawl rate differences within the nesting season. However, within most strata, we do not have replicates of crawl rates with which to calculate a variance. This problem was solved by assuming the coefficients of variation (CV's) of all crawl rate estimates (aerial counts per flight) were equal at a level of 11.68%.

Using the above data, the number of nests in Florida in 1980 are calculated as:

Florida Nests = [38(69+245)+15(93.5+552)
+15(126+747)+14(94+966)+15(34+423)
+15(21+28)+18(1+35)](0.8428)(0.5921)
= 28837

The variance of the number of aerial crawls was calculated using a CV of count data of 11.68%, expanding by the square of the number of days in a stratum and summed over all strata. Then the delta approximation was used for the ground truth correction and the nests per crawl ratio to compute total variance. This method assumes that the two ratio correctors and the number of aerial crawls are independent estimates. The resulting standard error of the estimate of the number of Florida loggerhead nests was:

SE(# Florida CC nests) = 2698

Georgia

Richardson et al. (1980) gave results of their 1980 aerial survey counts of fresh crawls. Their surveys covered 98% of the nesting habitat in the state of Georgia on each day of flying. The resulting counts were:

Date	Aerial Crawls
5/16	0
6/1	42
6/15	35
6/30	61
7/14	47
7/30	15
8/13	2

Peaking of crawls within the season is still indicated by this data. Therefore, the use of time strata was continued.

Richardson et al. (1980) indicate that "nearly all nesting on the Georgia coast occurs between 20 May and 10 August. However, their aerial data shows crawls to occur as late as August 13. Additionally, Stoneburner (1980) showed crawls to begin at Cumberland Island, Georgia on May 19 and end on August 23. In this analysis we will assume that the nesting season is May 19 through August 23. As before, the time strata were of approximately equal interval length except for the ending and beginning intervals. Therefore, the time strata and aerial counts were:

Time Stratum	Dates	Days	Georgia Aerial Crawls/Day
1	May 19-June 7	20	42
1	June 8-June 22	15	35
3	June 23-July 7	15	61
4	July 8-July 21	14	47
5	July 22-Aug 5	15	15
6	Aug 5-Aug 23	18	2

Corrections for ground truth of crawls and nesting to crawl ratio were the same as used for the Florida data, previously discussed. Additionally, calculation of the Georgia nest variance assumes that the CV of a flight's crawl count is the same as in Florida, i.e., 11.58%. Finally, the Georgia estimate must be divided by 98%, since the surveys only covered 98% of the suitable habitat. It is assumed that this factor was measured with a binomial variance of 0.0196. Given the above assumptions the following results were obtained.

$$\# \text{ Georgia Loggerhead Nests} = [20(42)+15(35)+15(61)$$
$$14(47)+15(15)+18(2)]$$
$$\cdot(0.5921)(0.8428)/0.98$$
$$=1629$$
$$\text{Standard error} = 284$$

North Carolina

Aerial survey data from the 1980 nesting season (Stansell, personal communication) were obtained from surveys from the Virginia border to Shackleford Bank (VA to SHAC) and from New River Inlet to Little River Inlet (NRI to LRI) in the following format

	# Aerial Crawls Counted	
Date	VA to Shackleford Bank	New River Inlet to Little River Inlet
6/2	3	3
6/16	3	5
7/1	3	17
7/15	13	44
7/29	11	-
8/12	2	-
8/28	0	-

Additionally, aerial crawl counts from a military helicopter were done on Onslow Beach, Brown Island and Bear Island. These three areas are between the New River and Little River Inlets. The data from these three areas were:

Date	# Helicopter Crawl Counts
5/31	2
6/13	2
6/14	2
7/1	2
7/2	12
7/11	4
7/12	6
7/17	3
7/31	11
8/1	4
8/11	7
8/12	6

Both data sets do not show a strong peak within the season, so stratification by time may not be necessary. Using the helicopter data, the mean count by flight before July 15 is not significantly different than that after July 15 (4.86 (SE=1.06) versus 6.20 (SE=1.39)), therefore, we assumed that the mean aerial count per flight for the New River-Little River segment was the same for the entire nesting season. The Virginia-Shackleford Bank segment was, also, assumed to have a constant mean rate. The results were:

	Mean Aerial Crawls/Flight	Standard Error
VA to SHAC	4.57	2.04
NRI to LRI	17.25	9.44

The nesting season in North Carolina began at least as early as May 31 and ended no earlier than August 12, using the above data. However, Stoneburner (1980) reports crawls occurring at Cape Lookout, NC on August 31. Therefore, the nesting season in North Carolina was assumed to extend from May 31 to August 31 (93 days).

The proportion of the North Carolina coast which was surveyed (VA to SHAC and NRI to LRI) was estimated to be 0.9 (with a binomial variance of 0.09). Therefore, the estimate of the number of loggerhead nests in North Carolina was:

North Carolina Nests = 93(4.57+17.25)(0.8428)(0.5921)/0.9

= 1125

Standard Error = 648

As can be seen, uncertainties about the data are reflected in a rather large standard error (coefficient of variation is 58%).

South Carolina

At this time, estimation suffers considerably from lack of available data and certain recorded but unverifiable assumptions. The following methodology assumes that the ratio of density of loggerhead nests between South Carolina and North Carolina is constant between years. The Draft Marine Turtle Recovery Plan (1981)* presents a synopsis of estimated number of nests by beach in North and South Carolina. The years 1977 and 1978 are the only two for which a usable set is in common. Also, these estimates are from a variety of sources which may or may not be biased. The results are:

	# Nests/km		Ratio
	South Carolina	North Carolina	SC/NC
1977	8.69	0.65	13.37
1978	12.24	0.97	12.62

For these two years the ratio is fairly constant with a mean of 13.00 and standard error 0.375.

* In preparation for the Southeast Regional Office of the National Marine Fisheries Service.

From the Draft Recovery Plan there are 503 km of nesting habitat in 1980 in North Carolina and 304.2 in South Carolina. Using the results from the previous section on North Carolina, the density of nests in North Carolina in 1980 was

NC Nests/km = 1125/503 = 2.2366

Standard Error = 1.2883

Therefore, the number of South Carolina nests becomes:

SC Nests = (304.2)(13.00)(2.2366)=8845

Standard Error= 5103

As indicated by the resulting standard error, this estimate is extremely imprecise. Additionally, a great deal of bias which is not reflected in the variance may be introduced by assuming that the densities between two states are constant, based on surveys using a variety of estimation techniques.

Number Nests per Female

Talbert, Stancyk, Dean and Will (1980) and Worth and Smith (1976) report on nesting frequencies in a South Carolina site and Florida site, respectively. The former data set was for the years 1973-1976, whereas the latter was from 1976. The estimates given by Talbert *et al.*(1980) for number of nests per female were

Year	Nests/Female
1973	3.21
1974	3.01
1975	2.29
1976	1.65

Mean = 2.54; Standard Error = 0.71

The method which was used to make these estimates was to divide the number of nests per year by the number of tagged turtles per year. Tag loss was discussed, but not incorporated in the statistics. Tag loss bias would tend to increase the estimate of nests/female. Additionally, tags were placed on animals which had made false crawls. Thus, the assumption was that an animal which crawled falsely had just (or shortly, would have) nested. If this were not the case, bias would introduced which would decrease the estimate. Also, this estimation procedure assumes that no nesting occurs outside the study area. Data from Worth and Smith (1976) indicate that re-nesting can occur at intervening distances of at least 95.2 km (mean = 13.2; standard deviation = 17.27), thus one would suspect that re-nesting does occur outside of most study areas. The effect of this bias is to increase the estimate of nests per female. The net effect of these biases indicate that the Talbert et al. (1980) estimates of nests per female are too high.

The data from Worth and Smith (1976) in which tags of only nesting animals are used yield an estimate of 1.88 nests per female. These data may also suffer from tag loss and migration bias.

The two sources of data provide estimates which are within normal variability of each other. However, they are from two isolated sampling areas in two different states. They were obtained from data which is considerably removed from the present (latest was 1976). Finally, the South Carolina data showed a declining trend over time. Thus, an extreme amount of uncertainty and variability exists in the estimate of nests per female. However, the estimate chosen for this study was the mean of 1.88 and 2.54, i.e.,

Mean Nests/Female/Year = 2.21
Standard Error = 0.72

Once again, it must be noted that this estimate is probably biased upward to some unknown degree.

Number loggerhead Nesting Females, 1980

The number of nests from the above analyses are:

	Estimate	Standard Error	2.5/♀	3.3/♀
Florida (East Coast)	28837	2698	11,534.8	8,738.4
Georgia	1629	284	651.6	493.6
North Carolina	1125	648	450.	340.9
South Carolina	8845	5103	3,538.	2,680.3
All	40436	5816	16,174.4	12,253.3

Therefore, by dividing by the number of nests per female we can arrive at the number of nesting female loggerhead turtles in the southeast U.S. in 1980.

Nesting Loggerheads (NC to FL, Southeast Seaboard) in 1980

$$= \frac{40436}{2.21} = 18297$$

Standard Error = 6516

If we assume that the estimate is distributed as a normal random variable, then 95% confidence intervals may be approximated by $\pm$ 2 standard errors. The results are:

Approximately 95% conf. interval =

$$5265 \leq \hat{X} \leq 31329$$

CONCLUSION

The estimation procedure presented has three general sources of error which should be considered in interpreting this report. First, there is a considerable amount of variability in the estimates due to the real variability in those factors being measured (number of crawls/day; number of nests/female, etc.). This source of variability must be accepted and it is reflected in the variance estimates.

The second source of variability is that caused by small sample sizes and sparse data. This causes high variances for the estimates of mean rates. Presumably, increased data acquisition could solve this problem. However, for the present exercise we must accept rather large standard errors.

The third source of error is biases introduced by improper methods and/or invalid assumptions. This source is by far the most serious because in many cases they cannot be assessed or measured. Effort was spent in this study to verify assumptions. However, many were not testable at this time. It is essential that the results be interpreted in light of possible biases.

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