A REPORT TO THE NATIONAL MARINE FISHERIES SERVICE

STATISTICAL ANALYSES OF SEA TURTLES

DATA DERIVED FROM THE 1979 CETACEAN AND TURTLE ASSESSMENT PROGRAM

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STATISTICAL EVALUATION OF PELAGIC AERIAL OBSERVATIONS OF MARINE TURTLES

OF MARINE TURTLES

INTRODUCTION

Until recently, data on offshore populations of sea turtles have been scattered and anecdotal, thereby precluding meaningful analyses of distributions in relation to variables such as depth, temperature, time of day, location, and certain biological parameters. Shoop et al (1981) have provided analyses of sea turtle data which address questions related to distributions and variables possibly correlated with distributions. That report represented a first effort of an ongoing project. This paper, using the same data, addresses several parameters in different ways and builds upon the Shoop et al (1981) report.

The Cetacean and Turtle Assessment Program (CeTAP) is a large scale survey program funded by contract with the Bureau of Land Management (BLM) to the University of Rhode Island, Howard E. Winn is the Scientific Director. Field work began in December 1978 and is presently ongoing. The purpose of the CeTAP project is to identify and enumerate marine mammal and turtle populations occurring from Novia Scotia to Cape Hatteras, North Carolina for use in environmental impact statements and to provide a monitoring base for endangered species as related to potential offshore oil drilling, production, and transport. Aerial surveys are used for determining: a) population estimates, b) areas of importance by species, c) temporal and spatial variation by species, and d) correlations between marine mammals/turtles and environmental factors such as depth, temperature, latitude, longitude and human activities.

Some of our findings, presented herein, differ with the 1979 CeTAP report because of different methodologies, selection of specific data, and

because additional data not included in the 1979 CeTAP report were added to the data base after release of the 1979 final report. As a result, when considered together, both reports provide bases for further investigations regarding the biology and analyses of data on sea turtle populations. Only the 1979 data derived from dedicated aerial efforts on loggerhead sea turtles (Caretta caretta) are considered in this report.

SAMPLING METHODS

Details of CeTAP sampling procedures and all methods are included in CeTAP reports and are only outlined here. Maps of flight tracks, area coverage, and other aspects are included in the 1979 CeTAP report. The CeTAP study area includes the outer continental shelf waters from Cape Sable, Nova Scotia to Cape Hatteras, North Carolina (Figure 1). The total area (81,154 square n. mi.) is divided into nine sampling blocks (A through I), surveyed independently. All sampling blocks are of approximately equal area with the exception of I, which is approximately half the size of the other sampling blocks.

Although separate and distinct sampling plans using different aircraft represent the CeTAP effort, this report involved only data collected from dedicated aerial surveys using a twin-engine Beechcraft (AT-11) equipped with a forward nose observation station allowing for direct observation of the flight track. Flight tracks were planned prior to the flights and were specially designed to meet criteria needed for population estimates. Hence, only dedicated survey data are valid for inclusion into most population related statistical analyses, and the methodology of these surveys follows.

Visual methods were used in all surveys for assessment; photographs were made for collection and verification of data. During dedicated flights, transects were flown at a standard altitude and speed of 243 m and 120 knots, respectively. A radar altimeter and special navigation gear allowed

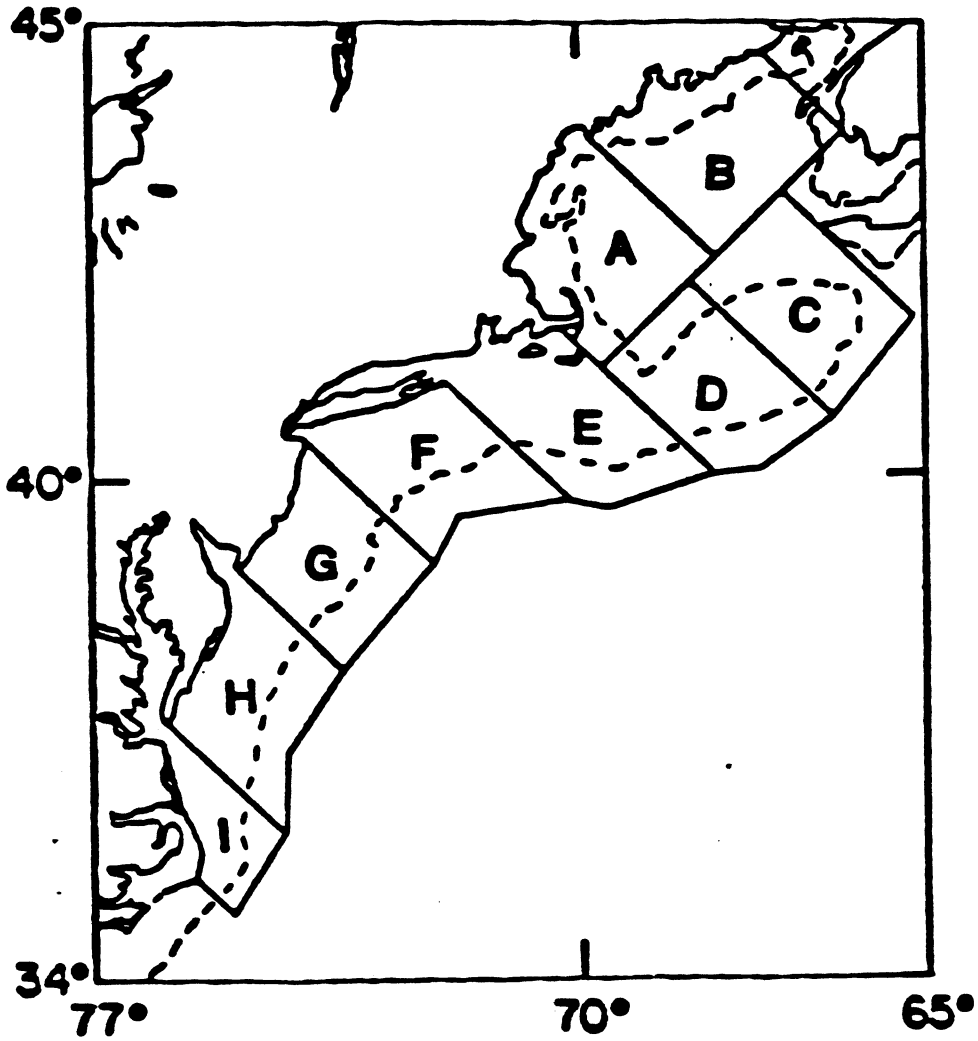


Figure 1. The CETAP study area from Cape Hatteras, North Carolina, to Nova Scotia, Canada, and between the coastline to the surface projection of the 2,000 m depth contour. For sampling purposes, the study area was divided into nine sampling areas or blocks depicted by letters A through I.

precision in these parameters. Two observers in the nose of the aircraft systematically scanned the water surface and made sightings along the track lines. During continuous observations, two sets of observers rotated, on about a one hour schedule, into the nose to reduce fatigue. The off-duty observers split duty either as data recorder or at a rear observation/ vertical camera control and rest station.

Observers made verbal notes through an inter-communications system which were tape recorded and hand recorded by an off-watch observer. Previous experience justified use of both methods since observations often come in too rapid a sequence to allow complete written notes. The redundancy of this system allowed for quality control.

The following information was recorded by observers at each encounter: time, distance (horizontal and vertical angle of observation using degree marks on the plexiglass and inclinometers), species identification (or other identifiable taxonomic group), distinctive features and coloration, relative direction of movement, associated fauna, behavior, visible oceanographic features (shears, slicks, rips, etc.), nearby human activities and other remarks. Other information such as transect number, altitude, heading, speed, aircraft, visibility (including sun angle and glare) and meteorological conditions were recorded at the beginning of the sample day, at each observer rotation, and when there were changes in these parameters.

In the AT-11, temperature, time, elapsed time, altitude, attitide, heading, speed, and location were recorded on film and magnetic tape every five minutes and upon each encounter when the vertical cameras were used. The verbal and hand written notes were correlated with the taped data using the real-time reference. Water depth determinations were made on the basis of the Loran-C coordinates subsequently plotted on depth charts. All data collection was by observers trained in aerial surveying techniques for

marine mammals and capable of marine turtle species identification. All data including vertical and oblique photographs, taped and written notes and radiothermographic and location measurements are indexed and catalogued. With this computerized data base, each encounter can be recalled by any number of index variables.

For dedicated survey flights, a random sampling design was used. The number of total tracks was determined as the number of parallel track lines of 2 n. mi. intervals perpendicular to a southwest-northeast line in each of the sampling blocks. Track lines were numbered sequentially and selected randomly without replacement using a random numbers table. Each transect had equal probability of selection. Each of the areas defined previously can be treated as an independent censusing region to allow inter-area comparisons.

By defining the boundaries of the census regions as running NW-SE the entire coastline out to the 2000 m contour was included for sampling. The advantages of running NW-SE tracks, other than (1) having total coast coverage, include (2) consistency, (3) minimization of dead time, (4) similar probability of coverage for all depth regions, and (5) equalization of sun glare problems. This sampling scheme was the same in all nine sampling areas and allows direct comparisons to be made between these areas. Dead time (i.e., the time between sampling of successive census tracks) was minimized because parallel tracks were connected by perpendicular legs. However, observations were made along cross-legs and in transit to maximize information.

The NW-SE oriented track lines tend to average out the effects of sun glare on observations. Because the orientation of the trackline was relative to the time of day, there were times when sun glare prevented census on one side of the aircraft. Flight times were balanced around noon.

Table 1. Sampling transects per block and survey for 1979 by dedicated AT-11 aircraft.

	SAMPLING BLOCK								
Survey	A	B	C	D	E	F	G	H	I
1	4	NE*	NE	3	4	4	4	5	3
2	4	4	4	6	7	4	4	4	4
3	4	4	4	4	4	4	4	5	7
4	6	5	4	4	4	4	4	5	4
5	5	5	4	7	4	4	4	5	4
6	4	4	4	4	4	4	5	2	1
7	NE	4	NE	4	4	4	5	5	4
8	5	5	NE	NE	4	NE	5	5	4

* NE indicates no transects were flown.

Sampling was conducted during 45 days windows in eight sampling surveys conducted between 23 January 1979 and 4 January 1980. The total number of transects flown per block for each survey is presented in Table 1. Sampling was conducted along transects when the Beaufort sea state was 3 or less and visibility was not less than two miles. Transects were considered "made good" when no less than 65% of the time was within those two limits. Only tracks "made good" are included in census analyses and then only the portions of the track within the above limits are considered.

To maximize the amount of correlative data, all observations from the AT-11 surveys are included when examining the relationship between turtle distributions and depth and water temperature.

In the CeTAP AT-11 line transect enumeration methods, observers reported sightings to the nearest .25 nautical miles from the flight line. The data are therefore in intervals of .25 nautical miles from the flight line. The resulting histograms can be interpreted as a generalized detectability curve.

Identification of all turtles was attempted to the species level. All identificaitons are accompanied by a reliability index of 1 for possible, 2 for probable, and 3 for positive. Only data for loggerhead turtles (*Caretta caretta*) are included here although leatherbacks (*Dermochelys coriacea*) were also observed in the CeTAP study. The relatively large numbers of loggerhead observations allow for definitive analyses.

DATA ANALYSIS

Our approach in this study looked at two related aspects. First, a determination of distributions of turtles in the study area and along transects was desired. Secondly, hypothesized factors that significantly affect sightability of sea turtles required definition to correct estimates of numbers.

All Caretta caretta sightings were classified by survey, block, sea state, and glare. This 8x9x4x3 contingency table was used to measure mutual independence of these factors in addition to identifying the spatial and temporal distribution of turtles relative to the study area and aerial effort. The model used to compute expected values is a log-linear model after Feinberg (1970) as:

$$e_{i,j,k,l} = \prod \left(\frac{n_{i,j,k,l}}{N}\right) N$$

where $e_{i,j,k,l}$ = expected numbers of sightings in cell i,j,k,l

$n_{i,j,k,l}$ = observed sightings in cell i,j,k,l

and thus $$\ln e_{i,j,k,l} = \sum \left(\frac{n_{i,j,k,l}}{N}\right) - \ln N$$

Because the sampling areas were of unequal size we corrected sightings by area in the following way before using them in a two-way contingency table which compared surveys and sampling areas. The proportion of each sampling area relative to the entire study area was computed. Using these computed proportions, all sightings were corrected such that each area was equal to the largest sampling area (H). Under the null hypothesis of the multiple X^2 test and the two-way corrected table, we assumed turtles were distributed such that the expected number of sightings was equal in all cells.

To determine how turtles were distributed throughout those areas when they were present, we considered depth, water temperature and time of day as variables determining distributions. Each variable was treated differently.

To examine to potential distributional effect of depth, turtle sightings were first classified into 25 fathom intervals. The resulting frequency distribution was then investigated with various regression

techniques. In this way the dependence of the distribution of sightings on depth can be determined.

Sightings made on transect for those transects made good were classified by hour or hourly intervals. Only sightings made in surveys 4-7 and blocks F through I, or where turtles were seen, were used in this analysis. Next, we computed total hours on transects made good and divided the number of sightings per hourly interval by the hourly aerial effort resulting in an estimate of sightings per hourly interval for each survey (4-7). Data were pooled over sampling block. We completed an ANOVA on corrected sightings. In this way, we determine if differences existed in sightings per hour between surveys.

Sightings were then classified by hour of occurrence and survey. For time of day we corrected sightings for effort and computed corrected rates for each hourly interval from 0800 to 1800 EST. To define trends we completed a non-linear regression on the frequency of sightings per hourly interval.

Finally, the distribution of turtles was described using regression techniques with water temperature as the dependent variable. Again, all sightings were used and were classified in 5°C intervals.

After describing distributions within the study area, we examined the distribution pattern of turtles along track lines. A tenet of line transect methodology (Burnham, Anderson and Laake, 1980) is that objects are randomly distributed along transects. To test for this assumption, we treated distance between turtles as a Poisson variable. In this way, we computed a mean (M) distance between turtles, with a variance (V) for each transect made good. If turtles are randomly distributed, V/M = 1. An X^2 test was completed to determine if the value of V/M deviated significantly from 1.0.

To test for observer differences, we used sightings made on transect in blocks and during surveys where turtles were present. In addition,

sightings used were accompanied by similar glare condition; thus controlling for differences caused by differing glare amounts. Observer's names were not consistently recorded during 1979; data for this analysis were limited and we could only utilize the X^2 test under the null hypothesis that observers are expected to see the same number of turtles on either side. Presumably, when more data are recorded a factorial ANOVA would be completed using glare as a covariate. All X^2 tests, regression models and ANOVA procedures, were completed with programs available in BMDP79.

In the estimation of density, three approaches or methodologies were considered. The first is based on sightings made only within .25 nautical miles on either side of the track line (Gates, 1979). This "Kelker" index results in a density estimate based only on sightings within the first strip interval (Δ) and is:

$$\hat{D} = n_1/2L$$

n_1 = sightings in strip 1

L = transect length

Δ = interval width of strip 1

$\hat{D}$ = density

This method assumes all animals are seen within strip 1 with a probability of 1.0. Any deviation from this assumption causes severe bias in the estimate of $\hat{D}$. A second method from Gates (1979) is a non-parametric estimator of the form:

$$\hat{D} = (3n_1 - n_2)/4L\Delta$$

n_1 = sightings in strip 1

n_2 = sightings in strip 2

Δ = interval width where $\Delta_1 = \Delta_2$.

This method also assumes that animals within strip 1 are sighted with a probability of 1.0. We did not compute density using this non-parametric approach as it was computed previously by CeTAP (Scott et al. 1981). A third approach simply utilizes the actual sighting curve to which a probability density function (pdf) is fitted. The pdf is then evaluated at $x = 0$, where X is defined as right angle distance from the track line. The value of $\hat{f}(0)$ gives the estimate of the sighting curve evaluated at right angle distance of zero or on the track line. Using the third approach, all density estimates are of the form:

$$\hat{D} = n\hat{f}(0)/2Lt$$

where $\hat{f}(0)$ is the function evaluated at right angle distance zero.

When examining sightings classified by strip interval, it was clear that almost all sightings occurred with strip 1 (0.25 n. mi. from the track line). The Gates model or negative exponential which is a parametric model is the likely pdf that could fit these data. This model was fit to those surveys and blocks where observations were made outside of strip 1.

RESULTS

To determine possible associations between survey, sampling blocks, sea state and glare, a 9x9x4x3 table was constructed cross-classifying each sighting by these factors. Results of the test of mutual independence are presented in Table 2. An examination of the one level factors show that all (survey, block, sea state and glare) are significant at $p < .001$ (Table 2). Of the two-way interactions all are significant at $p < .05$. Notably, not one of the higher order interactions was signficant at $p < .05$. The number of sightings made on a survey for those legs made good (i.e. 65% of transect completed) by survey and block corrected for area of sampling block are presented in Table 3. Results of the X^2 test suggest that turtles were seen more frequently in areas F, G, H, and I during surveys 4-7 than in other

Table 2. Results of X^2 test to determine mutual independence and levels of association between surveys, sampling block (block), glare amount (glare) and sea state.

1 Way	EFFECTS	DF	X^2	P
	Survey	6	83.79	< .005
	Block	6	80.95	< .005
	Glare	2	33.20	< .005
	Sea State	2	118.56	< .005

2 Way	EFFECTS	DF	PEARSON X^2	P
	Survey x Block	36	74.49	< .005
	Survey x Glare	12	51.24	< .005
	Survey x Sea State	420	469.76	< .05
	Block x Glare	420	758.73	< .005
	Block x Sea State	420	491.39	< .01
	Glare x Sea State	432	785.76	< .005

Table 3. Number of *Caretta caretta* in each block by survey. Total numbers were corrected such that all sampling were of equal area. Included is the computed X^2 value for 48 degrees of freedom (X^2_{48}) compared to the X^2 value at P = .005 for 48 degrees of freedom.

	BLOCK								
Survey	A	B	C	D	E	F	G	H	I
3	0	0	0	0	0	0	0	0	1.01
4	0	0	0	0	0	0	1.53	60.32	12.62
5	0	1.72	0	0	1	2.60	48.98	22.80	19.52
6	0	0	0	0	1.29	9.63	28.26	10.98	0
7	NS	0	NS	0	0	0	8.76	30.72	87.12
8	0	0	NS	NS	0	NS	0	0	6.69

Table 4. Computed variance to mean ratios using inter-sighting distance on transect. Included with V/M values for each sampling block by transect number for surveys 4-7, are X^2 value and level of significance (p). When the value of V/M is less than one the distribution of turtles is uniform; when V/M = 1, the distribution is random; when V/M > 1 turtles are clumped.

Survey Number	SAMPLING BLOCK F	G		H				I	
4				16 15.59 264.99 <.005	48 22.89 320.33 <.005	53 30.38 352.18 <.005	54 15.05 135.51 <.005		12 19.77 59.35 <.005
5		18 10.25 123.10 <.005	41 36.37 472.63 <.005	10 19.80 138.61 <.005	32 8.46 33.82 <.005	41 32.35 98.83 <.005			11 2.11 4.52 <.250*
6	24[1] 31.33[2] 187.98[3] <.005[4]	35 11.74 35.22 <.005	12 12.11 133.81 <.005	7 3.24 10.42 <.005					
7				12 37.45 112.38 <.005	53 2.08 4.17 <.250*	51 0.35 1.00 <.950*	15 1.95 13.63 <.100*	11 .33 2.62 <.990*	24 12.38 111.32 <.005

* not significantly different at p < .05

1) transect number
2) V/M value
3) X^2 value
4) p value

FIGURE 2. NUMBER OF CARETTA CARETTA OBSERVED ON DEDICATED AT-11 SURVEYS IN 1979 BY SURVEY NUMBER

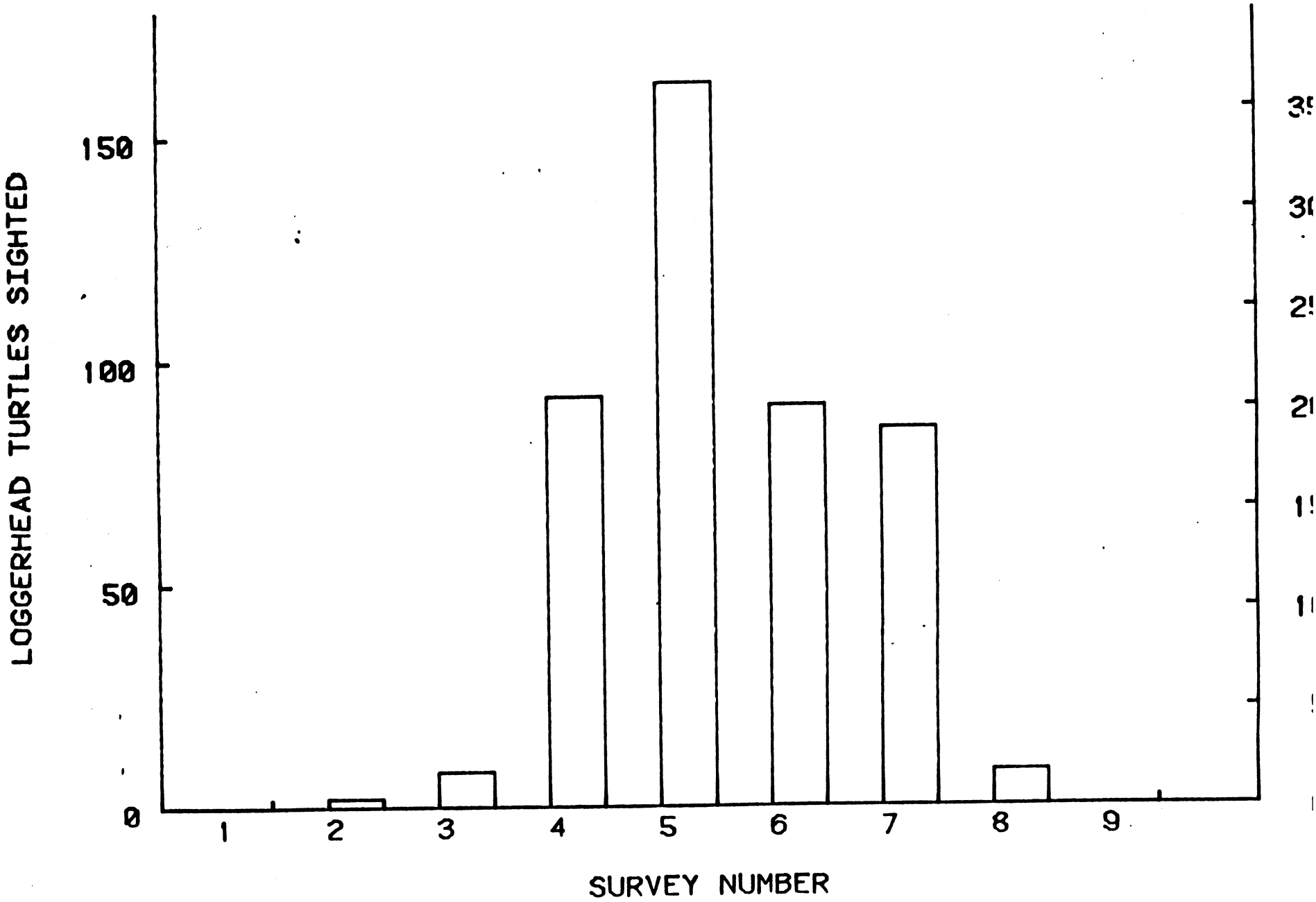
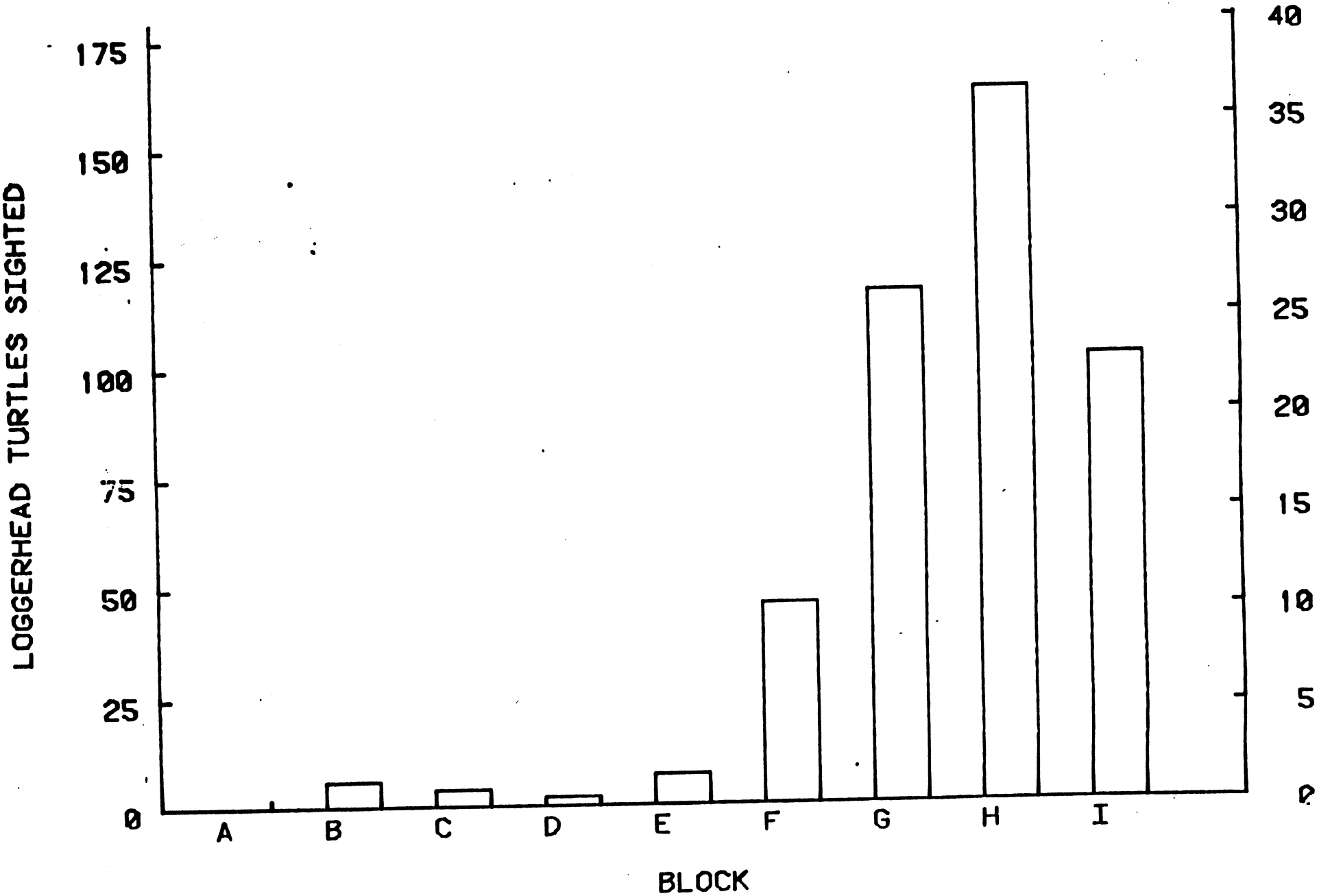


FIGURE 3. NUMBER OF CARETTA CARETTA SIGHTED BY DEDICATED OBSERVERS IN 1979 BY BLOCK



surveys and blocks, a result that is not unexpected as these areas are the southernmost (i.e., warm water) areas within the sampling area. Surveys 4 through 7 were completed in May-June, July-August, August-September, and October-November, respectively. When examining the sightings by block and survey (i.e. month) there is a concentration of loggerheads in the southernmost area (1) during the autumn, or on survey seven.

The distribution of absolute sightings by survey and block are presented in Figures 2 and 3. Again these figures show more turtles were sighted during surveys 4-7 and areas H-I than during other surveys and in other blocks.

To determine if turtles were distributed randomly along transects, the distance between sightings to the nearest hundredth of a nautical mile was first computed. We could not distinguish between turtles sighted on the track line and those sighted within strip 1. Turtles sighted within strip 1 were treated as if they were on the track line. If turtles are randomly distributed, the ratio of variance to mean distance between sightings (V/M) is one (Pielou, 1977). A X^2 goodness of fit test was completed under the null hypothesis that V/M = 1 (Table 4). For all blocks and for all surveys, computed X^2 values were significant at $p < .05$. We conclude from our computed values of V/M that turtle sightings are not randomly distributed along flight lines but by the same analysis the sightings are contiguously distributed along lines. Using our V/M, ratios a negative binomial fits the inter-distance measurements. Thus, we conclude that turtle sightings in 1979 were clumped along transect lines. These results show that sightings occurred with greater frequency on near-shore portions than off-shore portions of the track line.

Sightings were classified independently by depth (25 fathom intervals), water temperatures (5° C intervals) and time of day (by hourly interval).

The frequency distributions resulting are presented in figures 4, 5, and 6, respectively. Regression anaalysis yielded the following for each frequency distribution. The mid-point of the depth frequency intervals best fit a power curve ($r = .94$, $p < .05$) of form:

$$y = (3.26 \times 10^2) \times -4.58$$

y = number of sightings

x = depth in 25 fathom intervals

The water temperature data also were best fit to a power curve ($r = .91$, $p < .05$) as:

$$y = (2.08 \times 10^3) \times 3.33$$

y = number of sightings

x = water temperature in 5°C interval

The distribution of number of sightings classifed by hourly interval was best fit to a parabolic curve of ($r = .75$, $p < .01$):

$$y = 90.83 + 41.10x + 1.66x^2$$

y = number of sightings

x = hourly interval

Numbers of sightings of Caretta corrected by hourly efforts and these values were compared in a two way ANOVA, the results of which are presented in Table 6. Here, it is shown that while the numbers of corrected sightings are not different (at $p < .05$) between surveys, there is a difference (at $p < .05$) between numbers sighted per hour. It appears there is a real peak in sighting from 1000 hours to 1500 hours, or around noon.

Counts of turtles made by observers on transect for equal glare conditions are presented in Table 7. Accompanying paired counts is the conputed X^2 value and level of significance (p). Of ten such pair-wise comparisons, two were signficantly different at $p < .05$. In these two

FIGURE 4. NUMBER OF CARETTA CARETTA SIGHTED BY DEDICATED OBSERVERS IN 1979 BY DEPTH INTERVAL

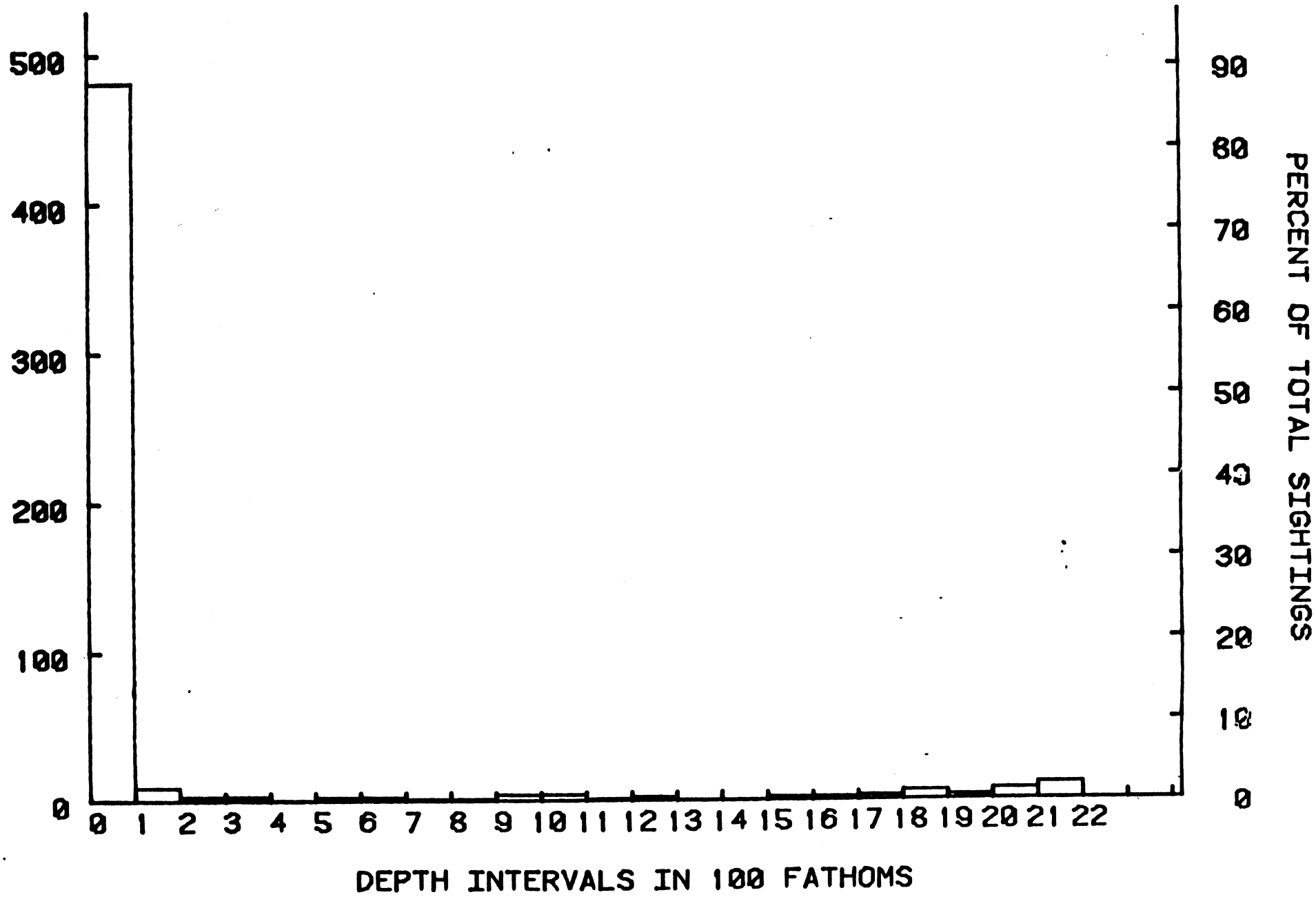


FIGURE 5. NUMBER OF CARETTA CARETTA SIGHTED BY DEDICATED OBSERVERS IN 1979 BY WATER TEMPERATURE

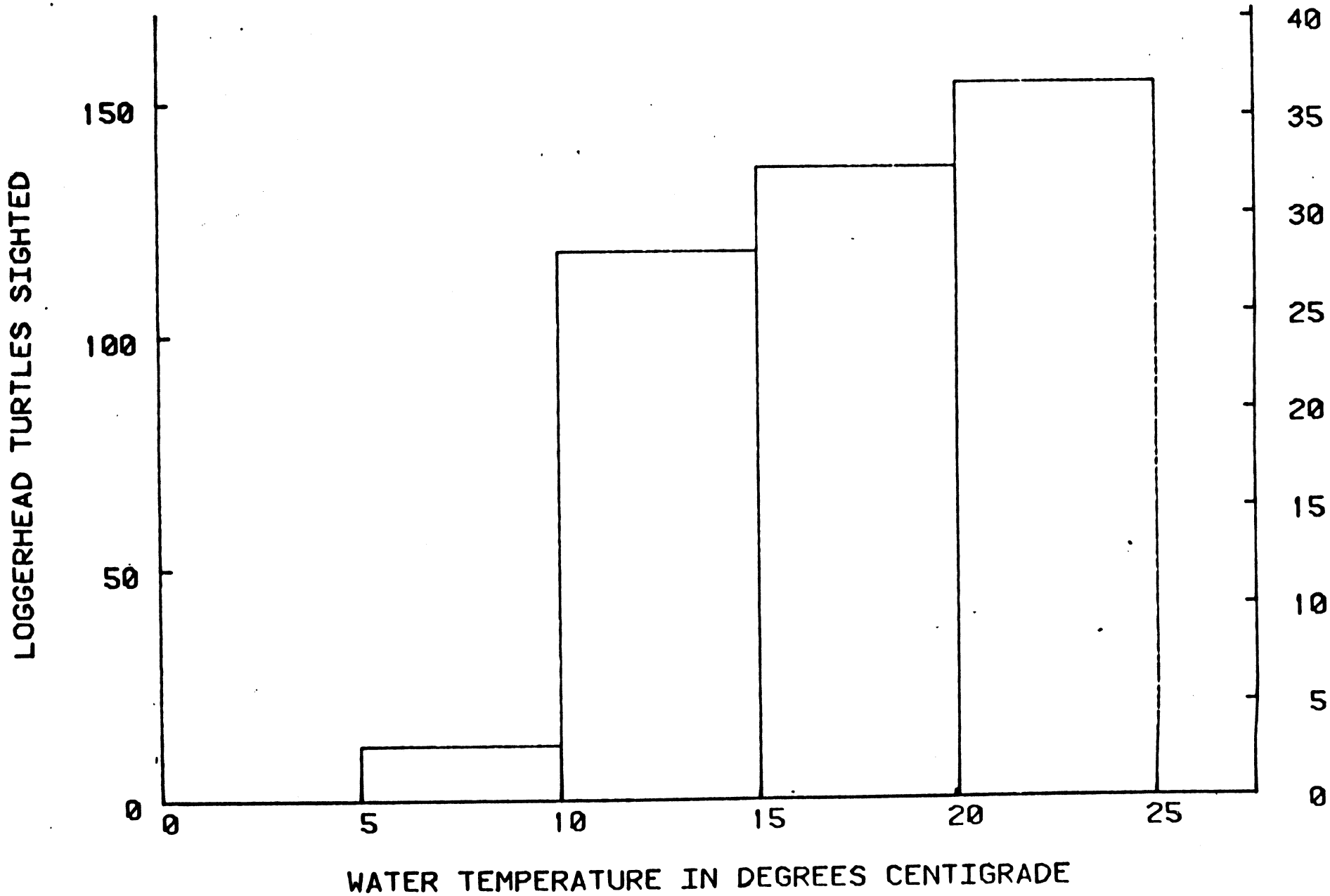


FIGURE 6. SIGHTINGS OF CARETTA CARETTA BY HOUR BY DEDICATED OBSERVERS IN 1979

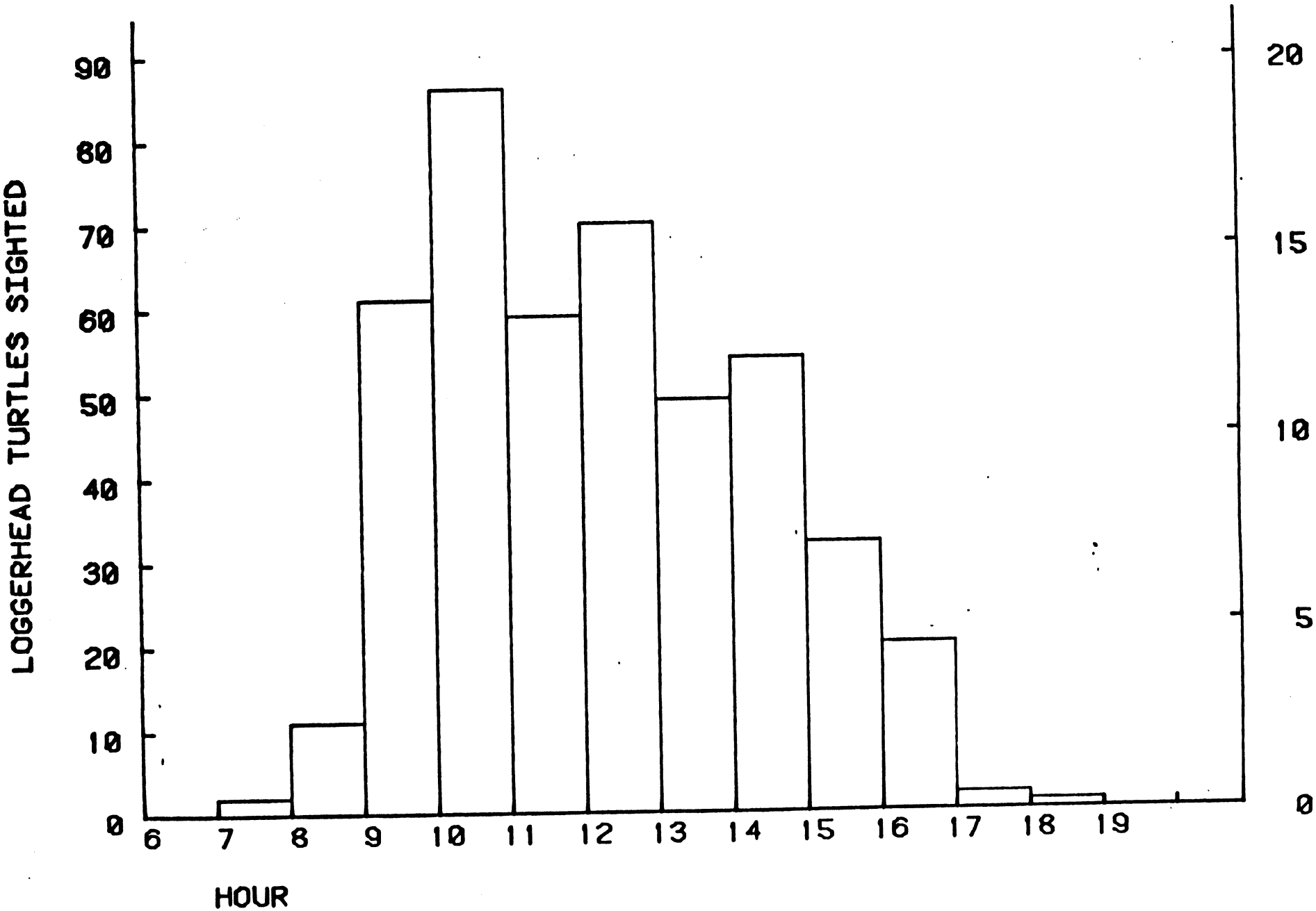


Table 6. Results of ANOVA on time of day using surveys as replicates and hourly intervals from 0800-1800 EST.

SOURCE OF VARIATION	DEGREES OF FREEDOM	MEAN SQUARE	F.	P.
Between surveys	3	4.35	1.45	< .250
Between hours	9	32.04	3.56	< .005
Residual		55.48		

cases, the same two individuals were paired as on-transect observers, and the same numerical relationship obtained.

Density estimates ($\hat{D}$) and total numbers ($\hat{N}$) of turtles present in each area for each survey were computed from the Kelker index (Table 8). This method assumes uniformity of the pdf through the effective one-half swath width. Because the first interval of the nose plexiglass was marked at .25 n. mi., this value is the minimum right angle distance boundary for a strip census. Thus, w = .250 (i.e. half-strip width) and with uniformity of the pdf through w = .250 then:

$$\hat{f}(0) = \frac{1}{.25} = 4.00$$

This value of $\hat{f}(0)$ is implicit in calculation of $\hat{D}$ when the Kelker index is used.

For surveys 4-7, and areas F-I, five of sixteen survey-area combinations include sightings made beyone strip 1 (i.e. > .25 n. mi.). These five samples were used to estimate $\hat{D}$ based on results of fitting the sighting distribution to a negative exponential (GATES model). Results of fitting a negative exponential to these six samples are presented in Table 9. Measures of variance accompany all estimates.

Discussion

The actual distribution and sightability of *Caretta caretta* is dependent on several factors which should be incorporated into any future sampling designs, within the CeTAP study area. Because the majority of turtles are migrants and/or feeding within the CeTAP study area, these results may not hold south of Cape Hatteras where turtles breed.

The assumption of randomness along the track line was rejected, except during October (i.e. Survey 7) in blocks H and I off the DELMARVA peninsula. Transects within this area extended out to 190 nm from the coast. In other

while on transect. Observers are identified by number. Included with number sightings is the X^2 value computed and level of significance (p).

Survey 4

OBS. 1	OBS. 2
3	0

$X^2 = 3.57$

$p < .100$

Survey 5

OBS. 1	OBS. 4
24	9

$X^2 = 21.19$

$p < .005$

OBS. 1	OBS. 3
3	4

$X^2 = 3.57$

$p < .100$

Survey 6

OBS. 1	OBS. 4
16	2

$X^2 = 14.44$

$p < .005$

OBS. 4	OBS. 5
1	1

$X^2 = 1.00$

$p \leq .5$

Survey 7

OBS. 1	OBS. 2
2	1

$X^2 = 1.67$

$p < .250$

OBS. 1	OBS. 6
1	6

$X^2 = 5.29$

$p < .025$

OBS. 2	OBS. 7
2	2

$X^2 = 1.00$

$p \leq .500$

OBS. 6	OBS. 1
3	3

$X^2 = 1.00$

$p \leq .500$

OBS. 2	OBS. 6
9	11

$X^2 = 1.33$

$p < .250$

1) Observer
2) Counts for each observer
3) X^2
4) Level of significance of X^2

Table 8. Kelker index density estimates (D) for *Caretta caretta*, computed for each dedicated survey and sampling block. Estimates are accompanied by variance estimates (V (D)) and estimates of the numbers of turtles (N) present at the surface.

	SAMPLING BLOCK								
Survey	A	B	C	D	E	F	G	H	I
1	0[1]			0	0	0	0	0	0
	0[2]	NE[4]	NE	0	0	0	0	0	0
	0[3]			0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	.0119
	0	0	0	0	0	0	0	0	3.00E-05
	0	0	0	0	0	0	0	0	34
3	0	0	0	0	0	0	0	.0059	.0100
	0	0	0	0	0	0	0	4.58E-04	2.10E-05
	0	0	0	0	0	0	0	48	33
4	0	0	0	0	0	0	.0121	.2584	.0582
	0	0	0	0	0	0	2.80E-05	9.36E-04	2.21E-04
	0	0	0	0	0	0	107	2120	195
5	0	.0046	0	0	0	.0353	.1596	.1117	.1590
	0	1.00E-06	0	0	0	1.30E-05	3.55E-04	2.64E-04	7.29E-04
	0	48	0	0	0	348	1313	916	534
6	0	0	0	0	.0094	.0488	.0733	.0449	0
	0	0	0	0	3.54E-04	7.20E-05	1.41E-04	1.50E-04	0
	0	0	0	0	97	481	603	368	0
7	NE	0	NE	0	0	0	.0197	.0841	.1974
		0		0	0	0	4.60E-05	2.34E-04	8.15E-04
		0		0	0	0	162	689	663
8	0	0	0	0	0	NE	0	0	.0098
	0	0	0	0	0		0	0	2.90E-05
	0	0	0	0	0		0	0	33

1) D 2) $V(\hat{D})$ 3) $\hat{N}$ 4) No Effort

Table 9. Results of fitting a negative exponential to each of five survey-block combinations for which sightings were made beyond .25 mm (outside strip 1). Inlcuded are X^2 values with degrees of freedom (DF), $\hat{f}(o)$, the standard error of the $\hat{f}(o)$, ($SE\hat{f}(o)$), density estimates ($\hat{D}$), and abundance estimates ($\hat{N}$).

Survey	SAMPLING BLOCK F		SAMPLING BLOCK G	SAMPLING BLOCK H
5	2.1809	1	.4215	
	3	2	3	
	2.97	3	5.79	
	0.9481	4	.9394	
	0.0262	5	.2311	
	258	6	1901	
	258			
6			0.0847	
			3	
			6.33	
			1.4821	
			0.1159	
			954	
7			.1282	14.7564
			3	3
			4.72	3.72
			2.0282	.7889
			.0232	.0782
			190	641

1) X^2
2) df
3) f(0)
4) SEf(0)
5) D
6) N

surveys and blocks when turtles were recorded, Caretta demonstrated clumping along the track line. Clumping was also demonstrated when examining the distribution of Caretta relative to depth. Most turtles were seen within the limits of the 100 fathom isobath. However, there was a slight increase in sightings beyond the 1500 fathom line.

The relationship of distribution with depth suggests that for loggerhead turtles, surveys in waters of more than 200 fathoms in depth will be less productive with comparable effort for surveys conducted in shallower water within the CeTAP study area. And, models assuming random distributions beyond 200 fathoms in depth may not be appropriate for estimates of variance in population size. While estimates of density with the entire sampling block are not effected by clumping, variance estimates are and must be adjusted accordingly (Gates, 1979).

Of interest is the finding that time of day was a significant variable in sighting turtles at or near the surface. Apparently, turtles are more visible from 0900 to 1500 hours. This may be due to the actual behavior of the observers rather than that of the turtles. We could not distinguish between these two possible effects.

The effect of glare was noted as significant in the CeTAP report. The effect of glare has been observed in many other aerial surveys and attempts are made to minimize its effect through the day via sampling designs. Undoubtedly, whenever a survey is to be conducted, the nullifying effect of glare is always incorporated into the experimental design.

Other effects examined such as the distribution of turtles relative to water temperature and the observer differences were either found to be inconclusive or expected. Turtles are present in thousands during the summer months up to and including waters off of Long Island, New York and were sighted in all blocks at some time during the year, except A, C, and D.

The presence and numbers of turtles in the various blocks through the year suggest movement throughout the summer to the Gulf of Maine. By mid-autumn (Survey 7), Caretta are apparently moving southward, such that by November-December (Survey 8), turtles were only found off the coast near Cape Hatteras.

Curiously, during Survey 5 (June) while Caretta were sighted in block B, the northernmost area, none were sighted in A, C, or D. Clearly, there is a northern concentration of turtles in the study area during mid-summer (Surveys 5 and 6) with fewer seen as the autumn progressed.

Because identification of actual observers was not always made, we could not examine differences between observer performance. When such data are available, we suggest the following approach to analysis. For all observations of an observer pair within a sampling block for each survey, a counting rate is computed. The rate is the number counted per minute in each area for each observer on watch. For each area, an average rate is computed and observer rates expressed as standard deviations from the mean. In this way, normalized rates can be considered the dependent variable in a regression with time taken to fly a transect (X_1);and time since start of flight (X_2). Thus, the counting rate (or attention) can be considered dependent upon boredom (X_1) and fatigue (X_2). We realize that it is impossible to include uncontrollable variables which affect both boredom and fatigue and that neither are simply a function of time.

One major bias in aerial surveys for sea turtles to date is correcting counts for survey efficiency. At this time, we assume for turtles that our density estimates are minimum values. When dive time data and surface activity time on sea turtles are available, we suggest correcting our estimates as noted below (after Caughley and Goddard, 1972). We assume the probability of a turtle being observed is constant for a given observer and

sightability conditions. In this way counts (successes) come from a binomial distribution, with p the proportion seen, from n independent trials (transects and surveys) such that the mean sightings are:

$$E(\bar{x}) = np \qquad (1)$$

$\bar{x}$ = mean number of sightings

p = proportion seen

n = numbers of turtles present with variance

$$E(s^2) = npq \qquad (2)$$

where $q = 1 - p$

Solving (1) for p and substituting into (2) and solving (2) for n gives:

$$n = \frac{\bar{x}^2}{\bar{x}^2 - s^2} \qquad (3)$$

Substituting (3) into (1) and solving for p gives:

$$p = \frac{s^2}{\bar{x}}$$

Thus, within an area or a given survey and transect for comparable sighting conditions, p, the mean proportion seen, is estimated per count directly from mean counts. This estimator is useful in evaluating survey efficiency within sampling areas for a given flight assuming the population size to be constant. The efficiency of different altitudes and speeds can be compared in this way. We have no data available to empirically test this method.

Another problem encountered is correcting for turtle dive times. Treating counts as from a binomial distribution, such that the proportion (of all turtles present) seen is p. The total turtles present (seen and not

seen, i.e. under water) is N. The number seen on any transect is n. Assuming independence of turtles then:

$$f(n) = \binom{N}{n} p^n q^{N-n}$$

and

$$\hat{N} = n/p \tag{4}$$

with unbiased variance

$$V(\hat{N}) = Nq/p \tag{5}$$

This assumes turtles are randomly distributed. If this is true, then flights should be restricted to no further than the 100 fm depth isobath. Assuming p will be estimated, we use (4) to correct our estimate of N.

Observer differences could conceivably be a major factor in the quality of aerial surveys of sea turtles. Although this study was unable to thoroughly analyze this potential problem, it should be considered on future studies.

Results from density estimation suggest that observation windows marked at .25 n. mi. intervals are inadequate for sea turtle surveys. Most sightings (ca. 98%) were made within the first strip. Turtles occur generally as single individuals. Compared to other CeTAP target species, the large whales and porpoises, turtles are small and behaviorally inconspicuous. Perhaps, all or most turtles are sighted within .25 n. mi. of the track line. If this is true, then $w < .25$ n. mi., the $\hat{f}(0) > 4.00$ and an increase of the computed value of $\hat{D}$ results. Thus, all our estimates are biased low, if $w < .25$ nm.

Of the three methods used to estimate density, all give results that are biased downward. Presumably, first discussions of the visual field could refine the right angle interval distance then an underlying pdf is discerned resulting in parametric estimation of density. Otherwise, the Cox-Eberhardt non-parametric method gives the most precise results.

RECOMMENDATIONS

1. Loggerhead turtles are not randomly distributed in the CeTAP study area. Pre-stratification in the Southeast region is not recommended based on the results of the CeTAP study. While non-randomness does not affect estimates of D, it does affect how V(D) is estimated.
2. The effective right angle distance which allows for sightability of turtles turtles is small. Right angle distance intervals of no more than 1/8 nm should be used and inclinometer readings should accompany sightings whenever possible.
3. The flights for pelagic assessments can be conducted from 0900 to 1500 local time. Thus, during the nesting season the early morning hours could be reserved for aerial surveys of nesting beaches.
4. We did not examine the effects of varying altitude on sightability of turtles, which needs to be determined. Replicates at 500, 750 and 1000 feet should be flown, under constant conditions with the same observers to determine to optimum altitude for sighting and identifying turtles. Our own experience dictates use of 500 feet flown at no more than 120 knots. Use of known size objects might facilitate such a study.
5. Any study area should be subdivided into sampling areas of approximately equal area. Within each area, the maximum potential number of transects at some selected interval width are placed. The number of transects randomly selected for sampling is determined as resulting in at least 10% aerial coverage.
6. To maximize the amount of information on the distribution and seasonal abundance of turtles, flights should be conducted at least seasonally, but with relatively small sampling windows (30 days) to avoid problems associated with migrating animals.

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