SEA TURTLE CONSERVATION PROJECT

BROWARD COUNTY, FLORIDA

1989 REPORT

Submitted by:

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and

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We gratefully acknowledge the dedicated efforts of **Sue Allen, Susan Bazin, John Braker, Rowena Cassady, Joe Cytacki, Paula Defelice, Judy Foss, Nancy Gilbert, Kraig Hankins, Judy Hicklin, Bill Laing, Bill Margolis, Kathy Maxon, Bob Miller, Craig Onque, Glen Pederson, Anthony Russo, Mike Srock, Terry Thompson, Bob and Jeannie Wershoven, and Gail Wojciechowski** who helped with the field surveys, night releases and/or hatchery sand replacement. Their dedication and hard work has made the project a success. We gratefully thank the owner and enployees of **Competition Cycle** who kept the all terrain vehicles running and provided a loaner ATV and a trailer. We also acknowledge the park naturalists and volunteers of the Broward County Park and Recreation Division at **Hollywood North Beach Park** who surveyed Dania, Hollywood and Hallandale beaches and whose data is included in this report. We acknowledge the following agencies and local governments for their cooperation in the completion of this project:

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Special thanks are due to **Mr. Hamilton Forman** for his ongoing support of Nova University and the turtle conservation projects through the years.

INTRODUCTION

Since 1978, the Broward County Erosion Prevention District (BCEPD) of the Broward County Environmental Quality Control Board has provided for the conservation of endangered and threatened sea turtle species within its area of responsibility, in accordance with provisions of the dredge and fill permits issued to the District by the U.S. Army Corps of Engineers, the Florida Department of Environmental Regulation and the Florida Department of Natural Resources. Broward County is within the nesting areas of three species of sea turtles: *Caretta caretta* (the loggerhead sea turtle), *Chelonia mydas* (the green sea turtle) and *Dermochelys coriacea* (the leatherback sea turtle). *C. caretta* is listed as a threatened species, while *C. mydas* and *D. coriacea* are listed as endangered species under the U.S. Endangered Species Act and Florida Law Chapter 370.

Since these statutes strictly forbid any disturbance of sea turtles and their nests, conservation activities involving the relocation of nests from hazardous locations (especially necessary along heavily developed coasts) require permitting by the U.S. Fish and Wildlife Service (USFWS). In Florida, this permit is issued to the Florida Department of Natural Resources (FDNR), which subsequently issues permits to individuals, universities and government agencies. This project was administered by the BCEPD and conducted by the Nova University Oceanographic Center under Marine Turtle Permit #129, issued to the BCEPD by the FDNR Institute of Marine Research, St. Petersburg, Florida. The BCEPD is especially concerned with any environmental effects of intermittent beach renourishment projects on shorelines and the offshore reefs. As part of this concern, the District has maintained the sea turtle conservation program in non-renourishment years to provide a continuous data base.

Operation of the program is competitively bid each year and a contract award is issued based on a selection committee review of submitted bids through a weighted point factor procedure. Nova University was awarded the contract to conduct the program during 1989.

In addition to fulfilling statutory requirements, the purposes of the project were:

1) to relocate eggs from nests deposited in sites threatened by natural processes or human activities and thus maximize sea turtle recruitment,

2) to accurately survey sea turtle nesting patterns to determine any historical trends and assess natural and anthropogenic factors affecting nesting patterns and densities,

3) to assess the success of sea turtle recruitment and of hatchery operations in terms of nesting success, hatching success and total hatchlings released,

4) to dispose of turtle carcasses, respond to strandings and other emergencies and maintain a hot-line for reporting of turtle incidents, and

5) to inform and educate the general public on sea turtles and their conservation.

MATERIALS AND METHODS

Beach Survey

Daily beach surveys commenced at sunrise, except at Fort Lauderdale where early beach cleaning necessitated a slightly earlier start. For survey purposes the County was divided as follows:

Beach	Length (km)	Boundaries
Hillsboro	7.0	Palm Beach Co. line to Hillsboro inlet
Pompano	7.7	Hillsboro Inlet to Commercial Blvd
Ft.Lauderdale North	8.6	Commercial Blvd. to Hatchery at South Beach municipal parking lot
Ft. Lauderdale South	2.0	Hatchery to Port Everglades Cut
Lloyd Park	3.9	Port Everglades Cut to Dania Beach fence
Hollywood-Hallandale	9.4	Dania Beach Fence to Dade Co. Line

Hollywood-Hallandale beach (also including Dania Beach) was surveyed by personnel from Hollywood's North Beach Park. Although data from Hollywood-Hallandale beaches are included in this report, this area was not included in Nova's area of survey responsibility.

Surveyors used all-terrain vehicles capable of transporting four turtle nests in plastic buckets. South Fort Lauderdale and Lloyd Park beaches were sometimes surveyed on foot due to vehicle break down. The usual motorized method was to mark and record nests and false crawls on the first pass along the beach and then dig and transport endangered nests on the return pass. Due to early beach cleaning in Fort Lauderdale, nests were picked up on the first pass along this beach.

After recording, crawl marks were obliterated. Where there were more than four nests requiring relocation, additional trips were necessary. On extremely heavily nested days the routine surveyors were assisted by additional personnel who transported nests to their final destination by car.

Endangered nests were defined as follows:

1) a nest located within 20 feet of the mean high water line
2) a nest located in an area with a high level of pedestrian traffic
3) a nest located near a highway or artificially lighted area defined as a beach area where a worker can see his own shadow on a clear night
4) a nest located in an area subject to beach renourishment
5) a nest deposited directly in existing, dense vegetation where the root systems might interfere with successful emergence of the hatchlings

Especially due to definition 3, 100% of the nests at Pompano, 96% at Fort Lauderdale North, 95% at Fort Lauderdale South and 94% at Hollywood-Hallandale were considered endangered and relocated to hatcheries or dark beach locations. Nests to be relocated were carefully dug by hand and transported in buckets containing sand from the nest chamber. They were then transferred to hand-dug artificial egg chambers of similar dimensions and lined with sand from the natural nest. Care was taken to maintain the natural orientation of each egg.

Nonendangered nests, mostly on Hillsboro beach, were marked and left in-situ. After hatching, approximately 100 of these nests were excavated. Hatching (actually emergence) success was defined as the percentage of spent shells (assumed to have yielded live hatchlings) compared to the sum of spent shells, piped eggs, eggs with arrested or no visible development and hatchlings dead in nest.

Hatchery Operations

As in previous years, eggs were relocated to three open beach

hatcheries located on Pompano beach near the foot of Atlantic Avenue, at the South Beach municipal parking lot in Fort Lauderdale, and adjacent to the south parking lot in John Lloyd State Park. The Lloyd park hatchery had a 3 inch gap along the bottom of the seaward face, allowing hatchlings to escape to the sea. After hatching, these nests were dug and counts of spent shells, hatchlings dead in the nest, piped eggs and eggs with arrested or no visible development were made. Hatching success was defined as the number of spent shells divided by total eggs relocated, times 100.

The Fort Lauderdale and Pompano hatcheries were not self-releasing due to the proximity of artificial lighting. Nests displaying a depression over the egg chamber, indicating eminent hatchling emergence, were covered with a screen cage or a bottomless plastic bucket to retain hatchlings, although the turtles sometimes escaped these enclosures by digging around them. Hatching success was defined as the percentage of relocated eggs resulting in live released turtles. After hatching commenced, the Fort Lauderdale and Pompano hatcheries were checked each night between 9 PM and midnight. After counting, hatchlings were released that same night in dark sections of Fort Lauderdale, Hillsboro or Lloyd Park beaches by allowing them to crawl through the intertidal zone into the surf. Hatchlings discovered at dawn in the hatcheries were collected and held indoors in dry styrofoam boxes in a cool, dark place until the following night, when they were released as above.

Because of the high nesting density and the high percentage of relocated nests, the Pompano and Fort Lauderdale hatcheries quickly filled. After June 9th at Fort Lauderdale and June 21st at Pompano, eggs from these areas were relocated initially to the Lloyd Park hatchery. When this facility also filled (in about 2 days), nests from Fort Lauderdale and

Pompano were relocated to Hillsboro Beach and endangered Lloyd Park nests were moved to the south end of the Park, which was not affected by the beach renourishment project. Later in the season, space again became available in the hatcheries, and open beach relocation was discontinued. Hatched nests in the hatcheries were completely dug out along with the surrounding sand and replaced with fresh sand before new egg chambers were dug.

Data analysis

The data was compiled, analyzed and plotted primarily with Lotus 123. The historical trend in County-wide total yearly nesting densities from 1981 to 1989 was determined by linear regression and correlation analyses. Total nests and false crawls were expressed per km for the six beach areas. Nests and false crawls per day at each beach were normalized for beach length and compared via 1-way ANOVA. When significant differences between groups was indicated, Student-Newman-Keuls (SNK) tests (Zar, 1974) were preformed to specify the differences between beach areas. Daily nesting success (nests/total crawls) patterns were plotted and mean daily nesting success between beaches and County-wide monthly nesting success were also compared via 1-way ANOVA and SNK tests with $\alpha = .05$. The weekly County-wide nesting pattern of *C. caretta* was compared with data from the 1988 season (Broward Co. Erosion Prevention District, 1988) with a Chi-square goodness of fit test.

During the peak nesting season (late May to early August) beach survey crews reported apparent increased nesting densities during full moon periods. This was statistically investigated. The daily nest count data were smoothed with a three point centered moving average. In order to represent the seasonal trend, a trend line was fitted by tenth order polynomial regression. The moving average was then detrended by subtracting the regression value for each day. Moon age was determined for midnight of each day of

the nesting season using Kepler, a public domain astronomy program by David Oshel (Ames, Iowa) for the IBM-PC. Moon age varies between 0 and 1 and is defined as follows:

Moon Age	Moon Phase
0.00	New Moon (starting to wax)
0.25	First Quarter (waxing)
0.50	Full Moon
0.75	Third Quarter (waning)
1.00	New Moon (final waning stage)

A more useful parameter representing moon phase was calculated as the absolute value of the sine of the moon age multiplied by 360 degrees. This parameter varies from zero on both the full and new moons to unity on both quarter moons. The moon phase parameter was compared to the detrended moving daily nest average from May 19 to Aug. 6 (peak season) by linear correlation and regression analyses. This was preformed on the combined Broward County nesting data as well as for the six individual beaches, and also for County-wide false crawls.

The effect of tide height and timing on sea turtle daily nesting patterns was similarly investigated. Nominal tide heights and times at Lauderdale-by-the-Sea (north central Broward County), for each day of the nesting season were generated using Tide•1 (Micronautics, Inc., San Francisco), a commercial tide prediction computer program. The daily heights and times of the nocturnal high tides were compared to the smoothed daily nesting pattern individually and in combination via step wise multiple linear regression analysis using Microstat (Ecosoft, Inc), a statistics program package.

Seasonal fecundity trends for *C. caretta* were analyzed by relating clutch size with the Julian date of clutch deposition by linear correlation analyses. Differences in mean clutch size for the six beaches were analyzed by 1-way ANOVA and SNK tests.

The overall hatching success (total hatchlings/total eggs) was calculated and compared with previous years. Hatching successes for relocated and in-situ nests were also compared for *C. caretta* and *C. mydas*.

The County-wide seasonal hatching success pattern was investigated by plotting the hatching success of each relocated nest versus the Julian date of its deposition. Linear correlation and regression analyses were used to analyze trends. The same analyses were preformed on data from Hillsboro relocated and in situ nests.

Since the Lloyd Park beach was the subject of a beach renourishment project during the 1989 nesting season, nest and hatch success data was compared with the previous year. The distributions of nests along the Lloyd Park beach in 1988 and 1989 were also compared from monthly nest totals in four approximately 1 km beach zones.

RESULTS

A total of 1695 sea turtle nests were surveyed County-wide in 1989. Of these, 1670 were *C. caretta*, 21 were *C. mydas* and 4 were *D. coriacea* nests. *C. mydas* nested only at Hillsboro (8 nests), Fort Lauderdale North (4 nests) and Lloyd Park (9 nests). *D. coriacea* deposited 3 nests in Hillsboro and 1 in Fort Lauderdale North. *C. caretta* nested from 20 April (Hillsboro) to 8 Sept. (Pompano). *C. mydas* nested from 2 June (Hillsboro) to 17 Aug. (Fort Lauderdale North) and *D. coriacea* nested from 24 April (Hillsboro) to 19 May (Fort Lauderdale North).

Figure 1A shows the yearly total nest count from Broward County since 1981 when coverage of the entire County commenced. Figure 1B shows the trend line fit to the yearly nesting data. The trend is positive but its slope is significantly greater than zero at only the 93.7 percent confidence level.

Figure 2 shows the County-wide nesting patterns of *C. mydas* and *D. coriacea* since 1981. There are no significant long term trends.

Figure 3A compares the weekly County-wide nest counts of *C. caretta* for 1988 and 1989. In 1989 *C. caretta* nesting densities increased more rapidly in mid May and were higher in mid and late July than in 1988. The same comparison for *C. mydas* (Fig. 3B) has too few data for meaningful generalizations.

Figure 4 shows the total County daily nesting pattern for the 1989, and Figure 5A-E compare the same data from the individual beaches (both sections of Fort Lauderdale combined). Table 1 gives nest totals for the individual beaches per kilometer for the entire season and the mean number of nests per day per km, listed in ascending order of the latter parameter. A 1-way ANOVA

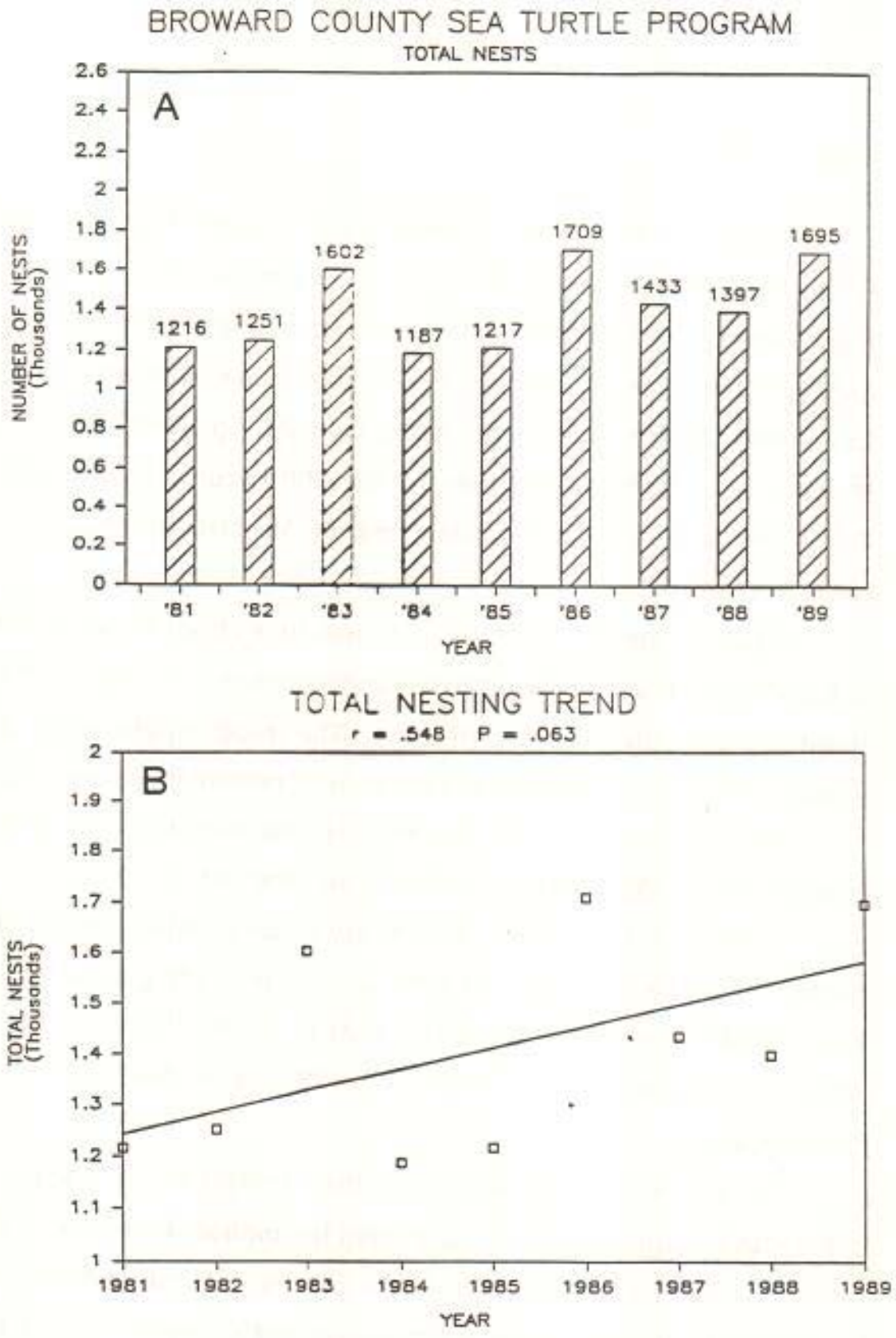

Figure 1: The historical pattern (A) and trend (B) of total sea turtle nesting in Broward County since full surveys began in 1981.

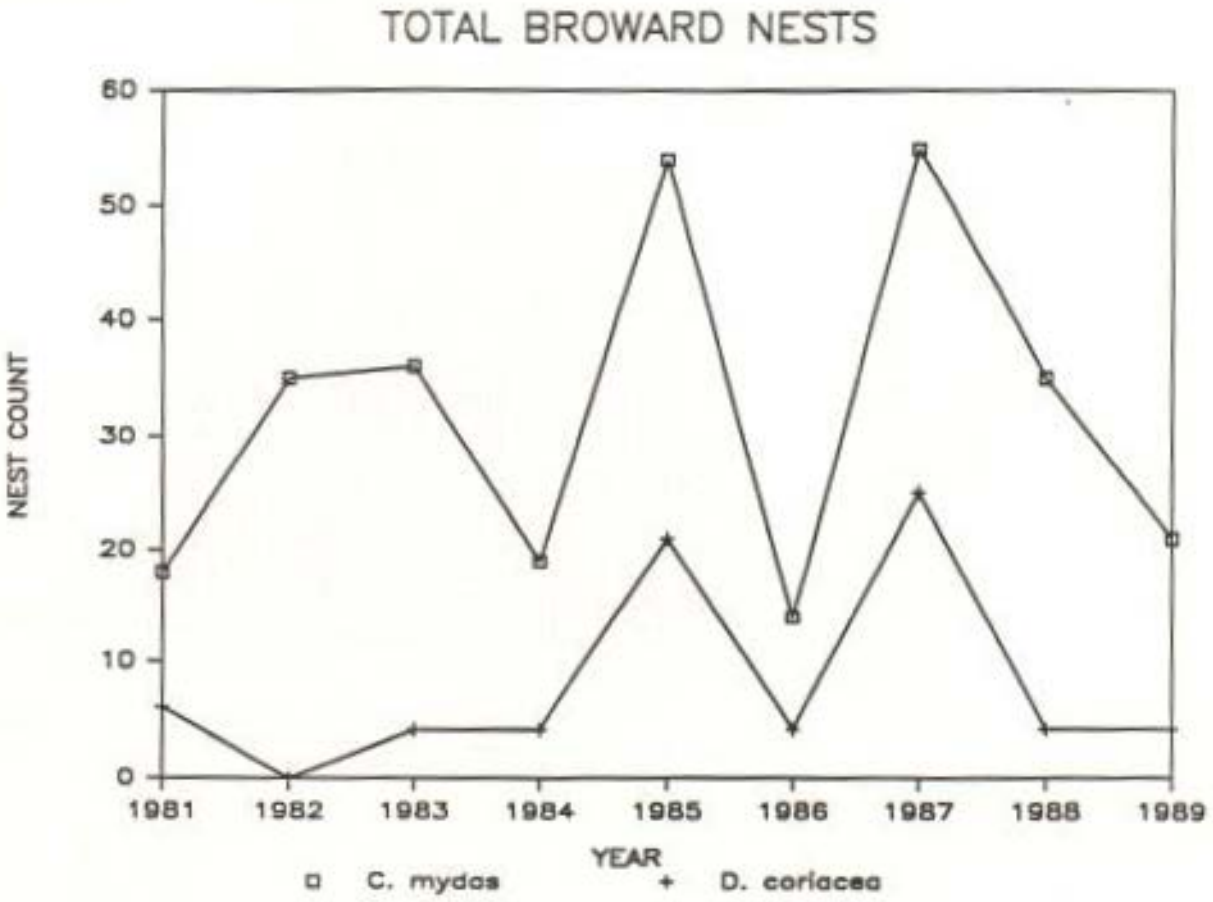

Figure 2: Historical nesting patterns for *C. mydas* and *D. coriacea* in Broward County since 1981

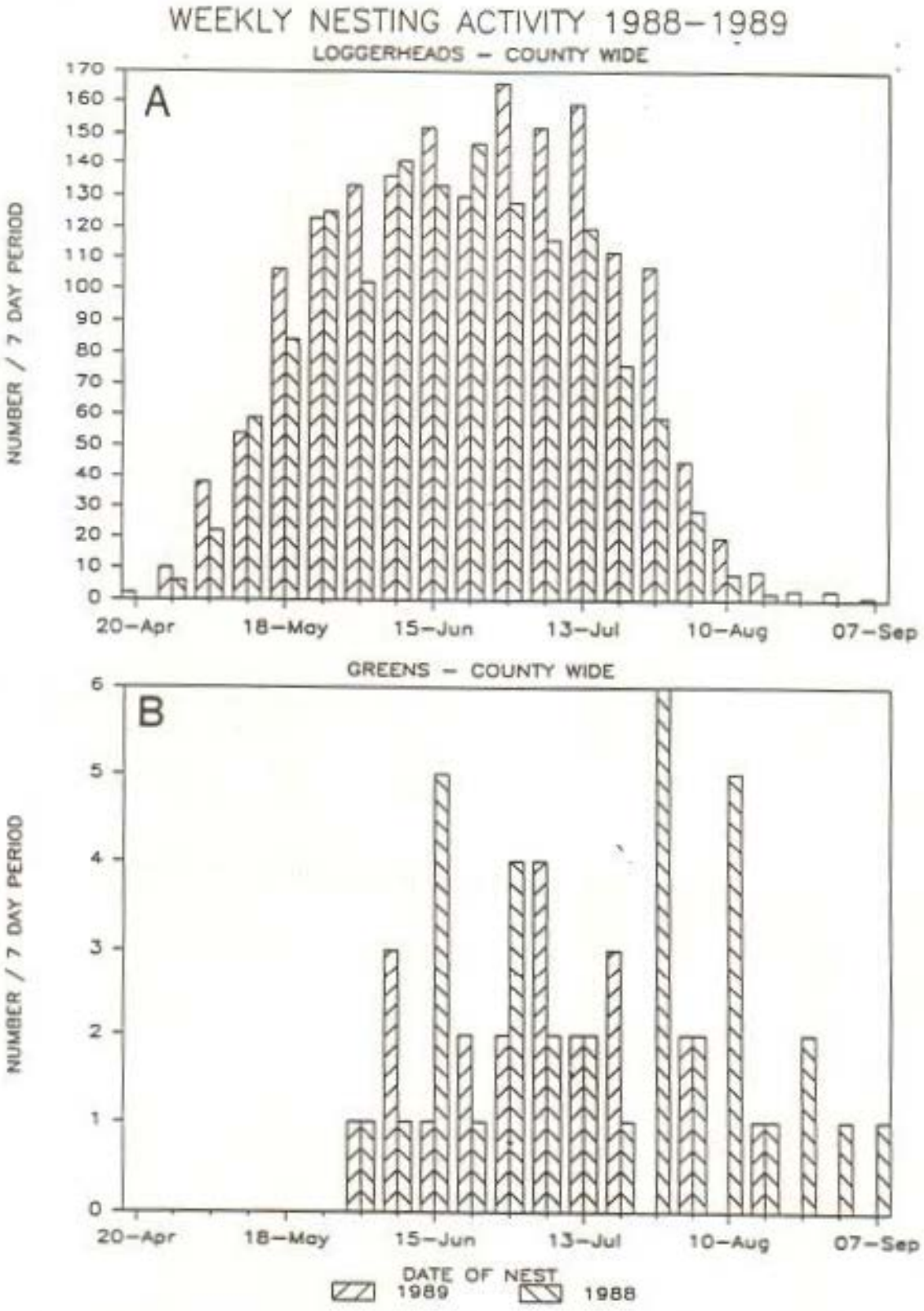

Figure 3: Comparison of weekly nesting during the 1988 and 1989 seasons for *C. caretta* (A) and *C. mydas* (B).

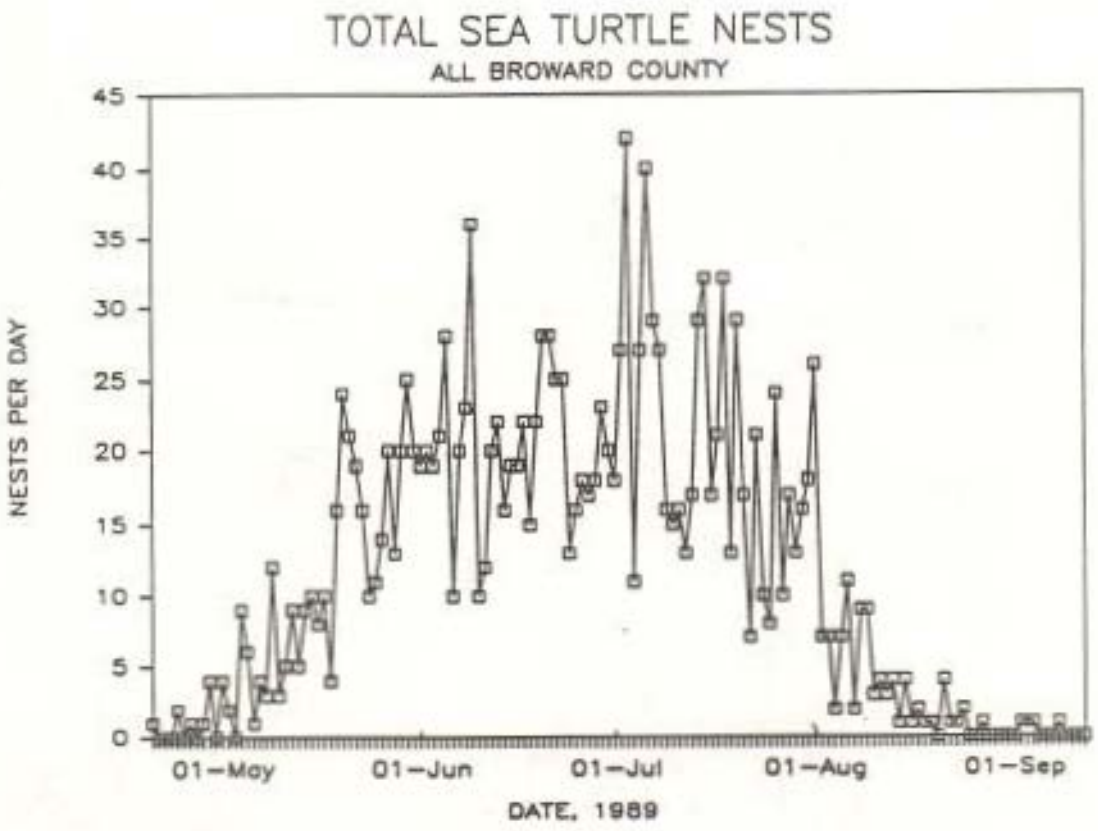

Figure 4: The seasonal pattern of daily total sea turtle nesting in Broward County, 1989.

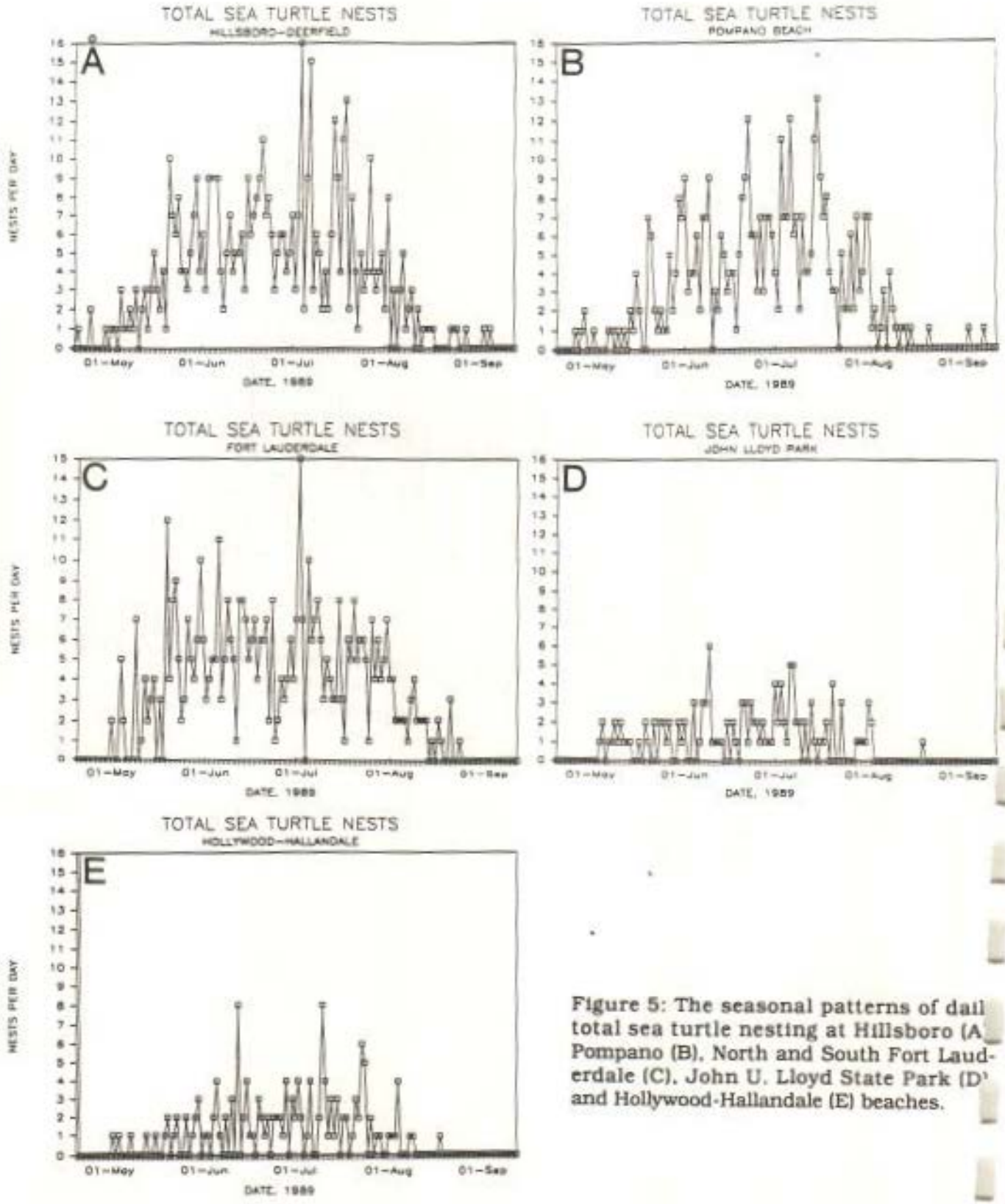

Figure 5: The seasonal patterns of dail total sea turtle nesting at Hillsboro (A Pompano (B), North and South Fort Lauderdale (C), John U. Lloyd State Park (D) and Hollywood-Hallandale (E) beaches.

Table 1: Total sea turtle nests, nests per kilometer and mean daily nests per kilometer for the six Broward Co. beaches. Vertical lines at right overlap groups of beaches where mean daily nests per km were not distinguishable in a SNK test at $\alpha = .05$.

Beach	Total Nests	Beach Length (km)	Nests per km	Mean Nests/km per day	
Hollywood-Hall.	141	9.4	15.0	.103	
Lloyd Park	130	3.9	33.3	.228	
Ft. Laud. North	359	8.6	41.7	.286	
Pompano	423	7.7	54.9	.376	
Ft. Laud.South	120	2.0	60.0	.411	
Hillsboro	522	7.0	74.6	.511	
Overall	1695	38.6	43.7	.318	

1565 w/o Lloyd

2774 old counts

on mean nests per day per km showed an extremely significant difference between groups ($P << .001$). Vertical lines at the left overlap groups whose means were statistically equivalent in a SNK test. Table 2 gives the same data for false crawls.

Figure 6 shows the daily County wide pattern of nesting success and Figure 7A-E gives the same data for the individual beaches. Extremely high nesting success was reported from the Hollywood-Hallandale area (Fig 7E), with only 30 false crawls all season. This is unusual since nesting success on this beach was 58.4 percent in 1988, with 90 false crawls (Broward Co. Erosion Prevention District, 1988). Table 3 gives the total and mean daily nesting success from the individual beaches. A 1-way ANOVA on mean daily nesting success showed significant ($P << .001$) differences between areas. The results of a SNK test investigating these differences are also given as in Table 1.

Figure 8 shows the County-wide seasonal trend of *C. caretta* clutch size. The trend line has a highly significant negative slope ($P<<.001$). Figure 9 shows the same data for the individual locations. The trends were negative in all cases, but significantly so only at Pompano, Fort Lauderdale North and John Lloyd State Park.

Table 4 lists mean clutch sizes for the individual beaches. A 1-way ANOVA showed highly significant differences between beaches ($P << .001$). The results of a SNK test are also given in Table 4.

Figure 10 gives the County-wide total daily nesting data with three point moving average and 10th-order polynomial regression line, compared with the moon-phase parameter. Figure 11 shows similar data (without the polynomial regression line) for the individual beaches and Figure 12 gives the same comparison for County-wide false crawls. The relation of the moon phase parameter to the detrended moving average of County-wide daily

Table 2: Total sea turtle false crawls (F/C), F/C per kilometer and mean daily F/C per kilometer for the six Broward Co. beaches. Vertical lines at right overlap groups of beaches where mean daily nests per km were not distinguishable in a SNK test at $\alpha = .05$. Hollywood-Hallandale omitted from the SNK analysis

Beach	Total False Crawls	Beach Length (km)	F/C per km	Mean F/C per km per day	
Hollywood-Hall.	30	9.4	3.2	.022	
Ft. Laud. North	223	8.6	25.9	.178	I
Lloyd Park	177	3.9	45.4	.311	I
Ft. Laud. South	93	2.0	46.5	.318	I
Pompano	408	7.7	53.0	.363	I
Hillsboro	455	7.0	65.0	.445	I
Overall	1386	38.6	35.9	.271	

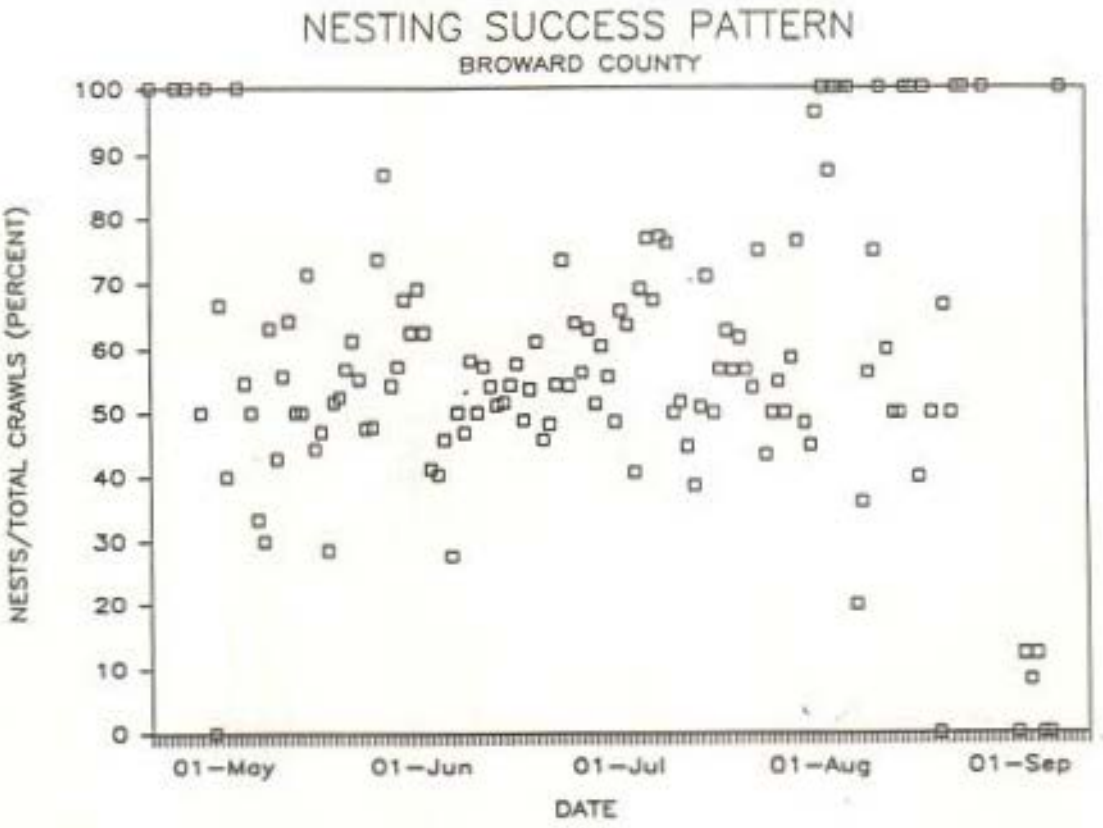

Figure 6: The County-wide pattern of total daily nesting success (total nests/total crawls) during the 1989 season.

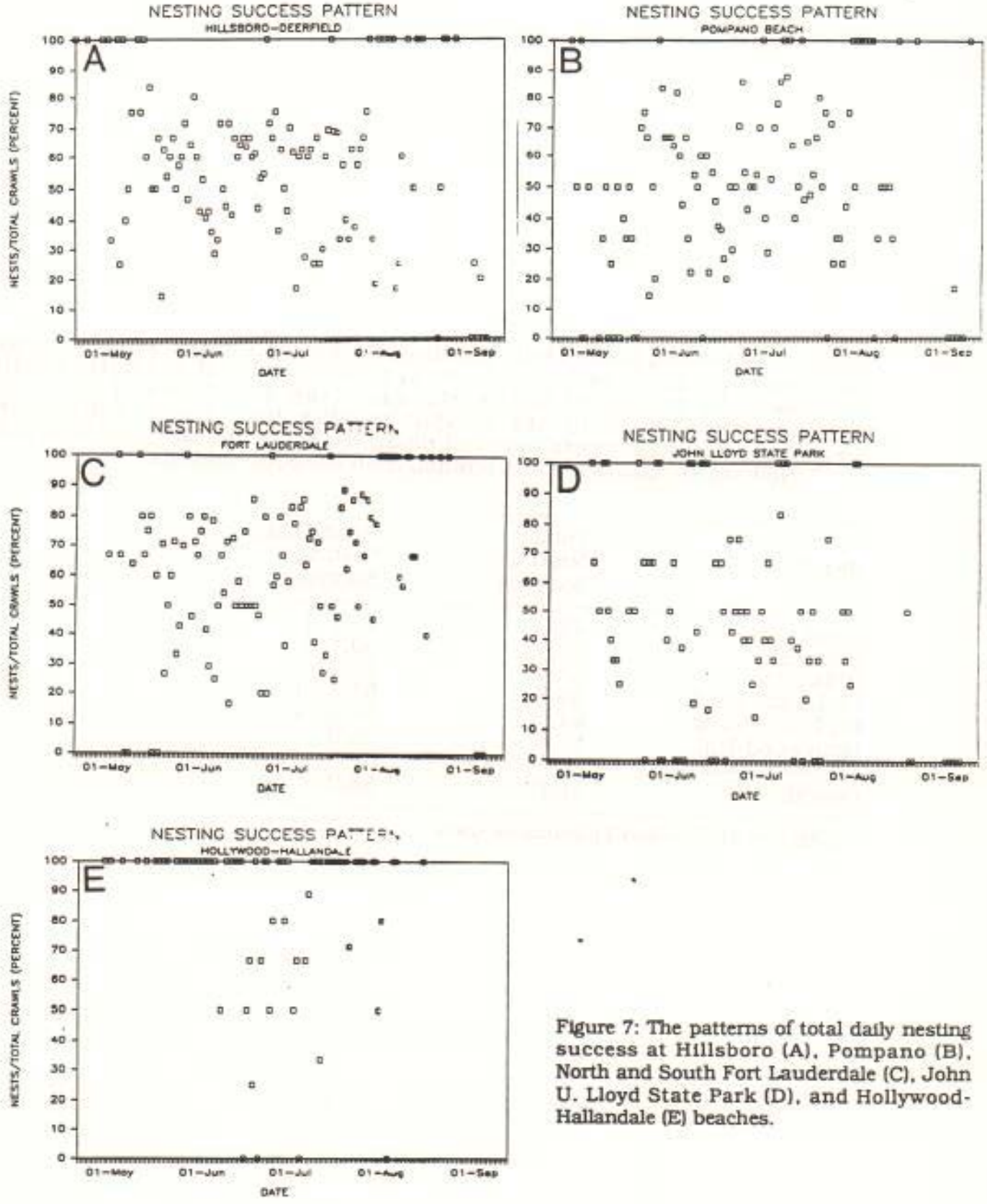

Figure 7: The patterns of total daily nesting success at Hillsboro (A), Pompano (B), North and South Fort Lauderdale (C), John U. Lloyd State Park (D), and Hollywood-Hallandale (E) beaches.

Table 3: Total and Mean Daily nesting success expressed as percentages. Total nesting success is total nests/total crawls. Mean daily nesting success is the average of daily nests/daily crawls calculated for each day of the survey. Vertical lines at right overlap groups of beaches where mean daily nesting success were not distinguishable in a SNK test at $\alpha = .05$. Hollywood-Hallandale was omitted from the SNK analysis.

Beach	Total Nesting Success	Mean Daily Nesting Success	
Lloyd Park	42.3	45.1	|
Pompano	50.9	50.1	|
Hillsboro	53.4	59.4	|
Ft. Laud. South	56.3	61.1	|
Ft. Laud. North	61.7	64.6	|
Hollywood-Hall.	81.6	84.9	
Overall	55.0*	56.2	

* Includes Hollywood-Hallandale data

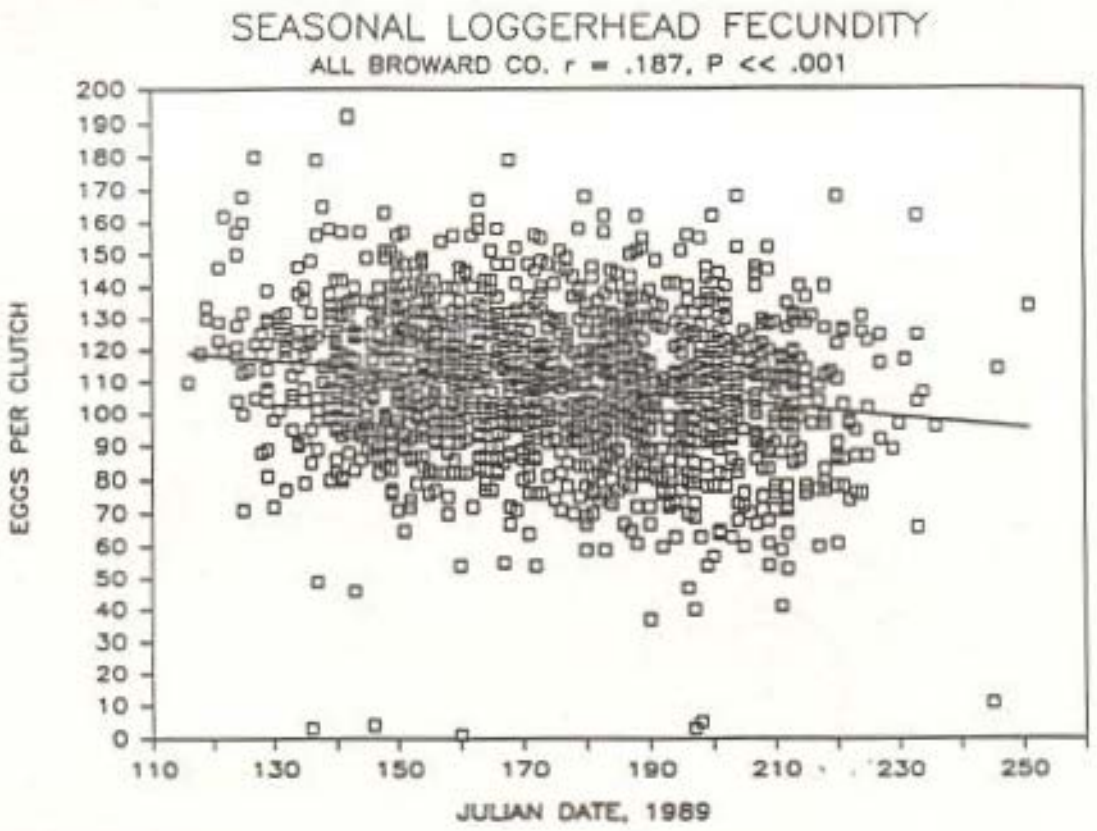

Figure 8: The seasonal decline in *C. caretta* fecundity (eggs per clutch) for all nests in Broward County.

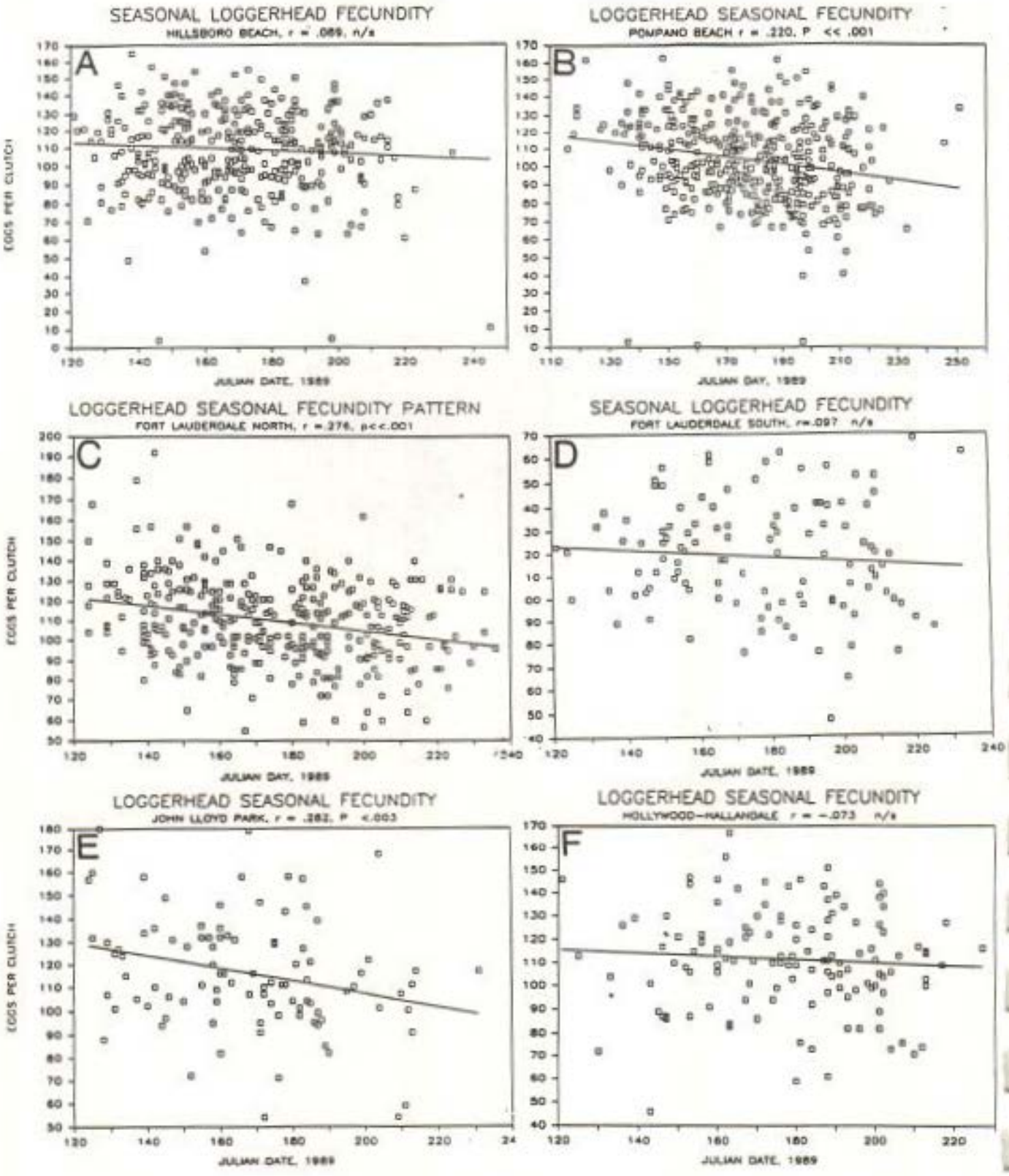

Figure 9: Seasonal patterns of *C. caretta* fecundity for all nests at Hillsboro (A), Pompano (B), North (C) and South (D) Fort Lauderdale, John U. Lloyd State Park (E), and Hollywood-Hallandale (F) beaches.

Table 4: Comparison of mean clutch size for *C. caretta* nests for the 1989 nesting season at six Broward Co. beaches. Vertical lines at right overlap groups of beaches where mean daily nesting success were not distinguishable in a SNK test at $\alpha = .05$.

Beach	Mean Clutch Size	Number of Nests	
Pompano	103.6	422	I
Hillsboro	107.8	360	II
Ft. Laud. North	110.0	345	II
Hollywood-Hall.	110.8	133	II
Lloyd Park	116.0	96	II
Ft. Laud. South	118.3	114	I
Overall	108.7	1470	

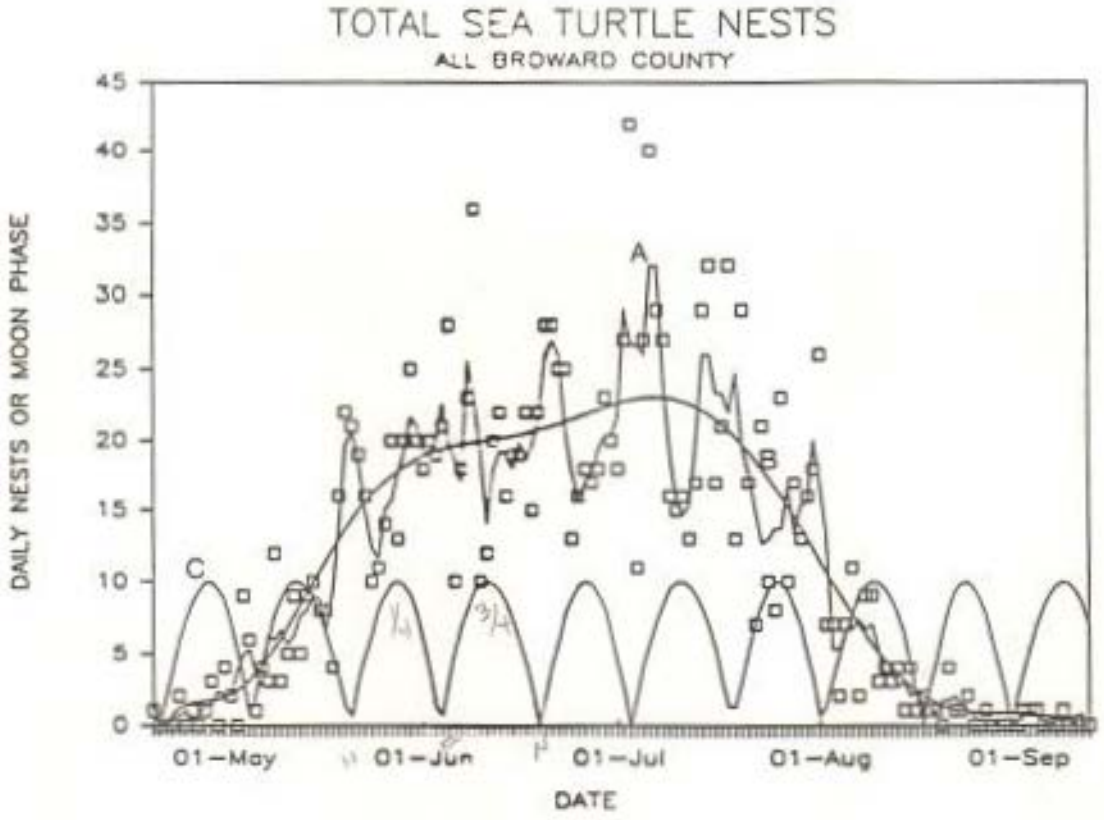

Figure 10: The seasonal pattern of total daily sea turtle nest (squares) for the 1989 season in Broward County, showing the three-point centered moving average (A) and tenth-order polynomial regression trend line (B), compared to the moon-phase parameter (C). Maxima in the latter indicate times of quarter moons; minima indicate full or new moons.

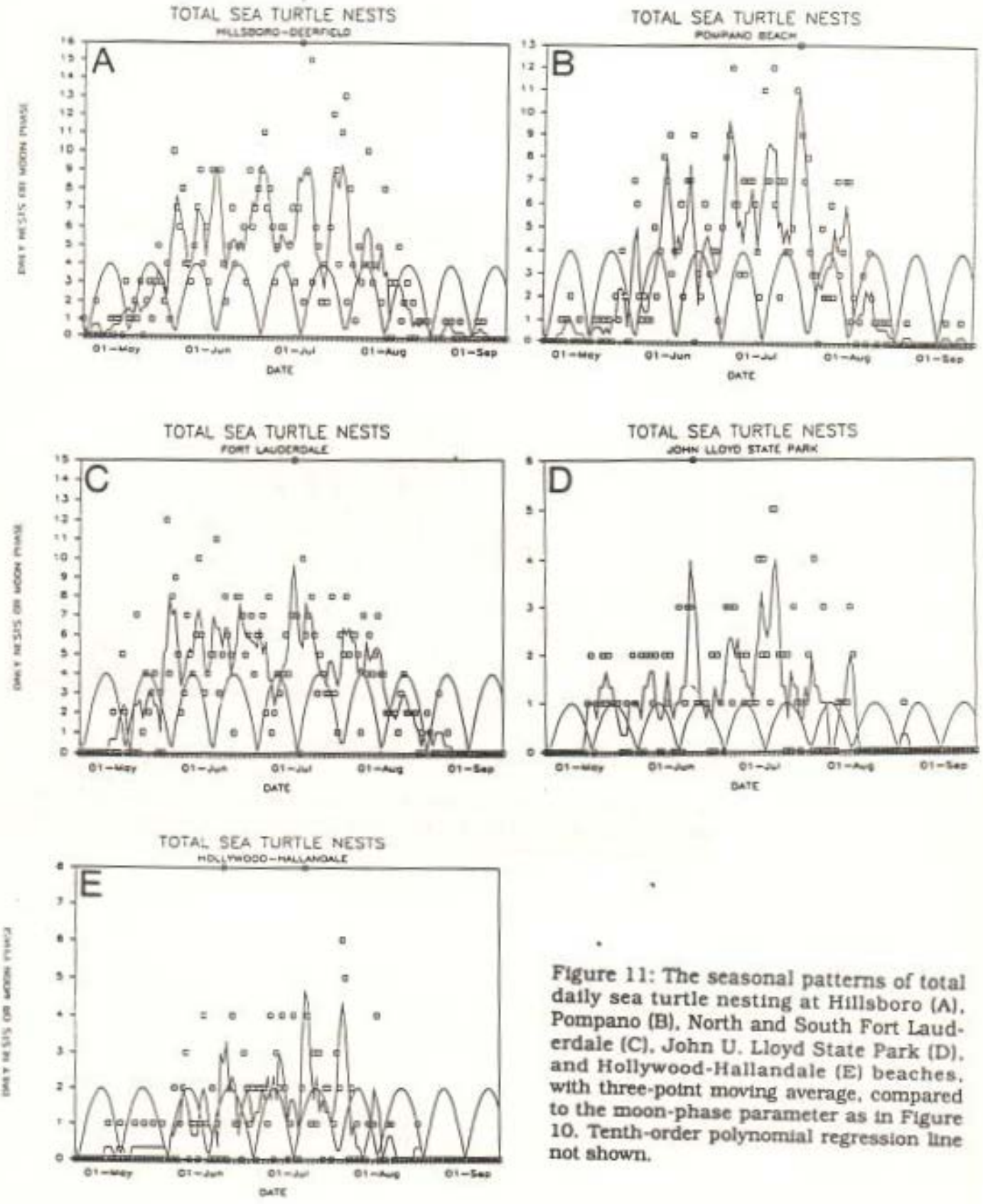

Figure 11: The seasonal patterns of total daily sea turtle nesting at Hillsboro (A), Pompano (B), North and South Fort Lauderdale (C), John U. Lloyd State Park (D), and Hollywood-Hallandale (E) beaches, with three-point moving average, compared to the moon-phase parameter as in Figure 10. Tenth-order polynomial regression line not shown.

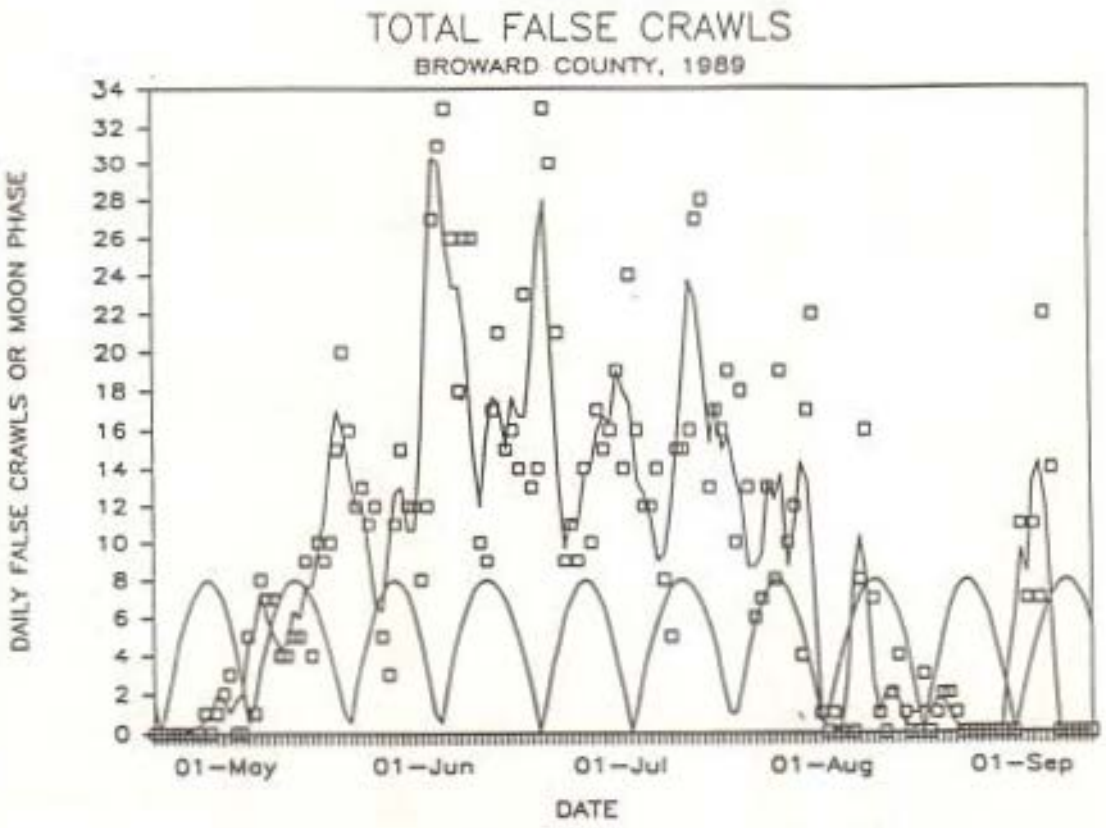

Figure 12: The seasonal pattern of total daily sea turtle false crawls for the 1989 season in Broward County. Lines and symbols as in Figure 10. Tenth-order polynomial regression line not shown.

nesting densities is shown in Figure 13. Figure 14 shows the same relationship for each beach. Figure 15 compares the County-wide daily nesting data (3 point moving average) with the time of the evening high tide.

Table 5 gives nest relocation and hatching success by beach, as well as a complete accounting of lost or destroyed eggs. The locations of some nests, which were relocated to open beach areas, were lost because people removed the markers. These nests could not be dug to determine hatch results and the eggs are listed as lost, but these nests probably hatched normally. All the relocated eggs from nests attacked by foxes and raccoons are listed as destroyed. Although some hatchling tracks were seen leaving these nests, no accurate hatching success data could be derived. All eggs in lost or partially destroyed nests were omitted from the calculation of total hatching success to avoid bias. Figure 16 illustrates the total number of hatchlings released each year of the project since 1978. Table 6 gives overall hatching success data for in situ nests and Table 7 shows hatching success for *C. mydas* and *D. coriacea*. Figure 17 shows overall hatching success patterns from relocated and in situ nests since 1981 when beach hatchery operations commenced. Figure 18 compares the monthly trends of egg incubation times for the 1988 and 1989 seasons.

Figure 19 shows the overall seasonal trend of hatching success for all relocated nests. There was a significant trend towards lower hatch successes in nests laid later in the season. Figure 20A-B indicate similar trends for relocated and in situ nests at Hillsboro.

Figure 21A compares the patterns of total sea turtle nesting in four 1 km zones at John Lloyd State Park in 1988 (pre-renourishment) and 1989 (ongoing renourishment project). Figure 21B compares the same data expressed at percent total nests for each year. Figure 22A-B compares the monthly nesting patterns in the same zones during 1988 and 1989.

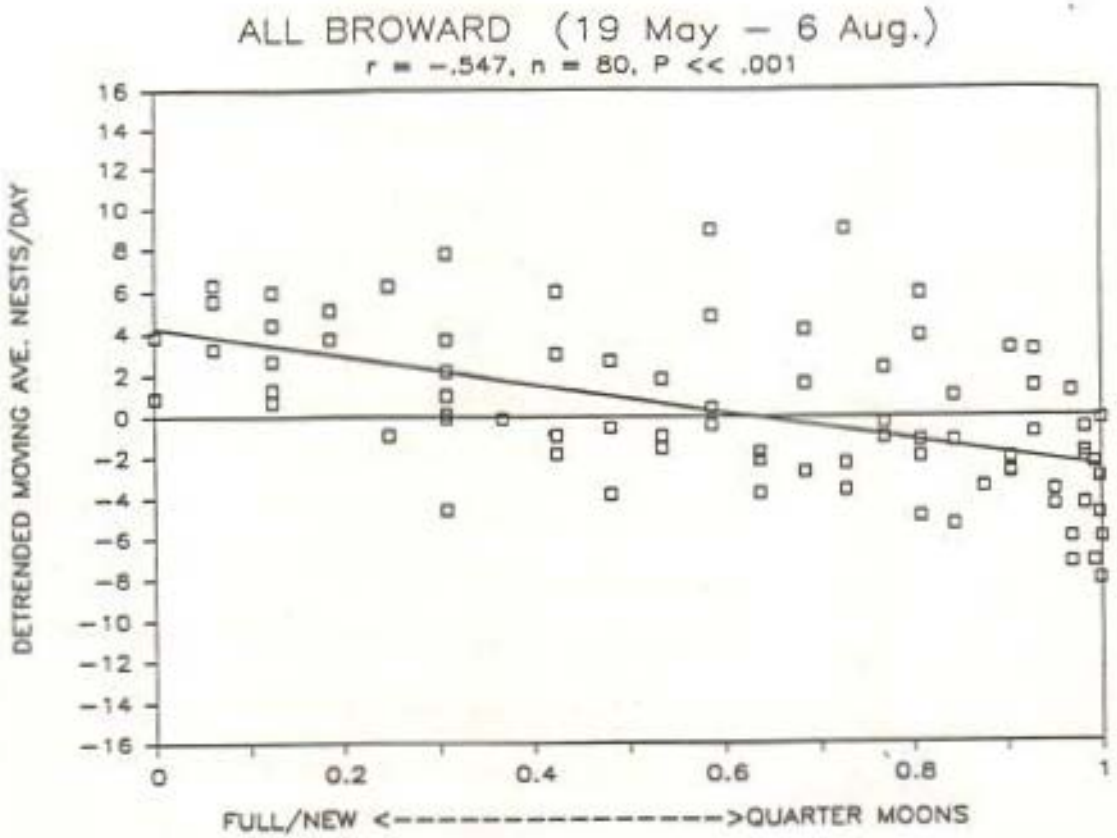

Figure 13: The statistical relationship of the County-wide detrended moving average nesting pattern and the moon phase parameter, with the linear regression line, correlation coefficient (r), number of data (n) and significance level (P).

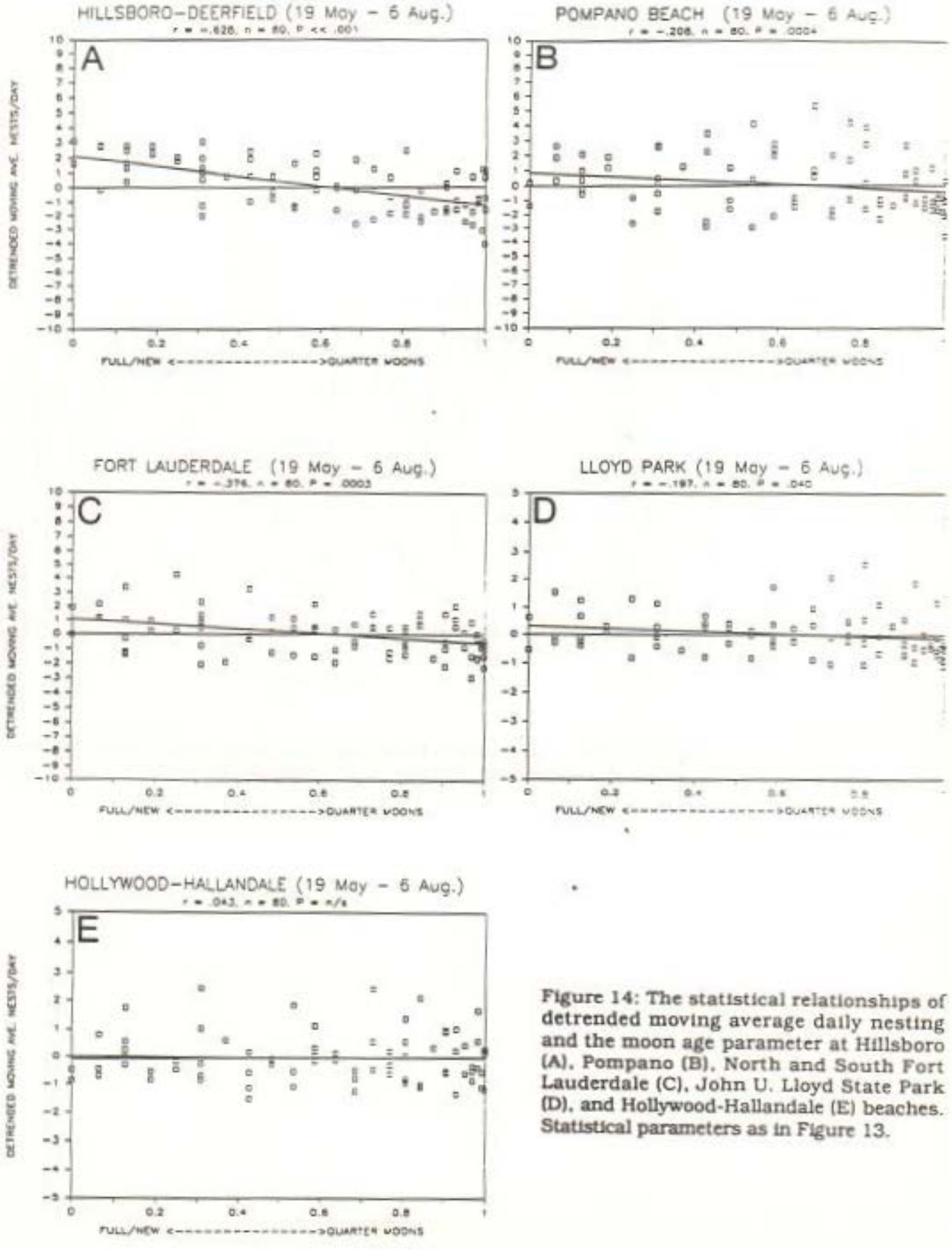

Figure 14: The statistical relationships of detrended moving average daily nesting and the moon age parameter at Hillsboro (A), Pompano (B), North and South Fort Lauderdale (C), John U. Lloyd State Park (D), and Hollywood-Hallandale (E) beaches. Statistical parameters as in Figure 13.

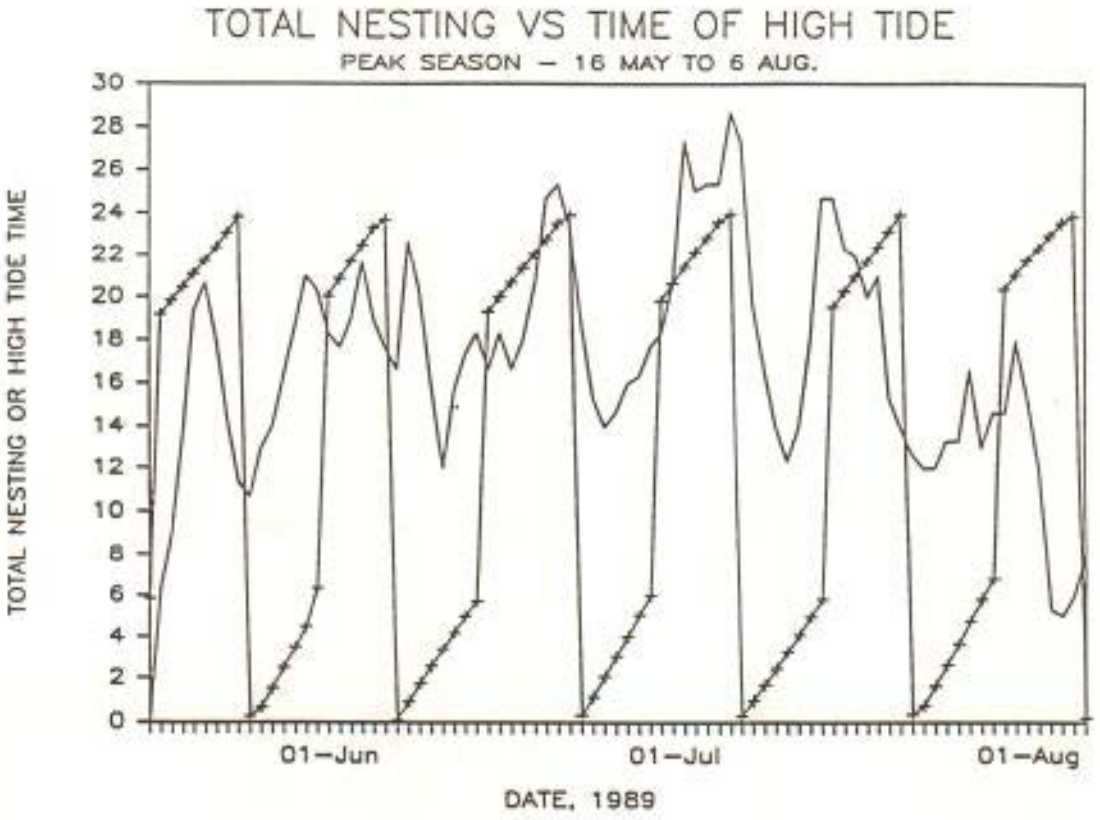

Figure 15: The relationship of the County-wide daily nesting pattern (lines) and the time of the nocturnal high tide (+) at Lauderdale-by-the-Sea.

Table 5: Comparison of overall nest relocation and hatching results by beach for all species combined

Beach	Nests Moved	Total Eggs Moved	Eggs Lost or Dest.*	Hatchlings Released	Overall Hatch Percent#
Hillsboro	273	29674	521[1]	19077	65.4
Pompano	423	43835	248[2]	30943	71.0
Ft.Laud.North	345	37911	799[3]	26061	70.2
Ft.Laud.South	114	13485	125[4]	8419	63.0
Lloyd Park	104	12205	505[5]	8884	75.9
Hollywood-Hall	133	14842		11238	75.7
Overall	1392	151952	2198	104622	69.9

* Eggs from nests which were relocated outside of hatcheries and could not be found because of removal of the markers are termed "lost". Many of these probably hatched normally. Eggs from partially predated nests are termed "destroyed", although some eggs hatched successfully.

Hatchlings released / (Total eggs moved - Lost or Destroyed)

1 125 eggs lost, 396 eggs destroyed

2 114 eggs as yet unhatched, 134 eggs to Discovery Center

3 799 eggs lost

4 125 eggs transferred to Discovery Center (fate unknown)

5 505 eggs destroyed

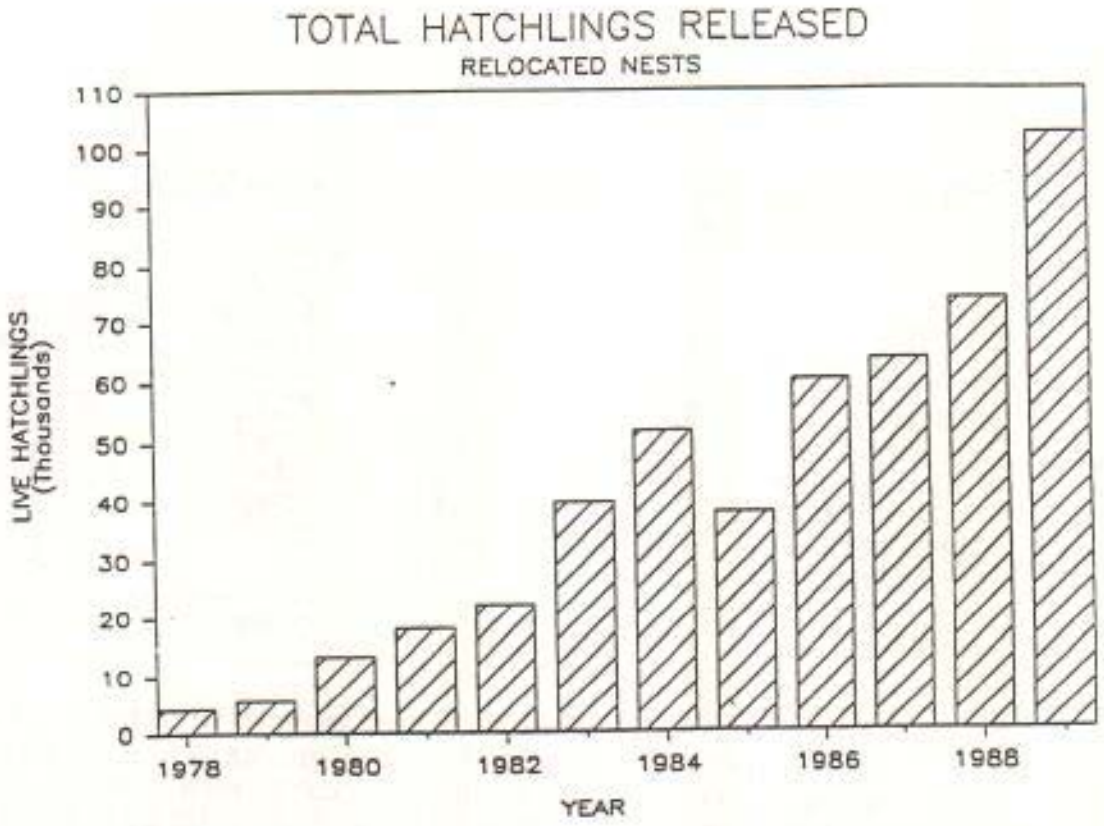

Figure 16) The yearly number of live hatchlings released from relocated nests since the Broward County Sea Turtle Conservation Program began in 1978.

Table 6: Overall hatching success for In Situ nests

Beach	Number of Nests	Number of Eggs	Hatchlings Released	Percent Hatching Success
Hillsboro	92	9742	6380	65.5
Ft. Laud. North	4	513	455	88.7
Lloyd Park	3	344	239	69.5
Overall	99	10599	7074	66.7

Table 7: Hatching success for *C. mydas* and *D. coriacea*.

Species	Number of Nests	Number of Eggs	Hatchlings Released	Percent Hatching Success
In Situ Nests				
C. mydas	3[1]	317	218	68.8
D. coriacea	1[2]	136	90	66.2
Relocated Nests				
C. mydas	12	1537	1058	68.8
D. coriacea	2	250	161	64.4
Overall				
C. mydas	15	1854	1276	68.8
D. coriacea	3	386	251	65.0

[1] 6 in situ nests not excavated. 5 at Hillsboro, 1 at Ft. Lauderdale North.
[2] 1 in situ nest not excavated at Hillsboro

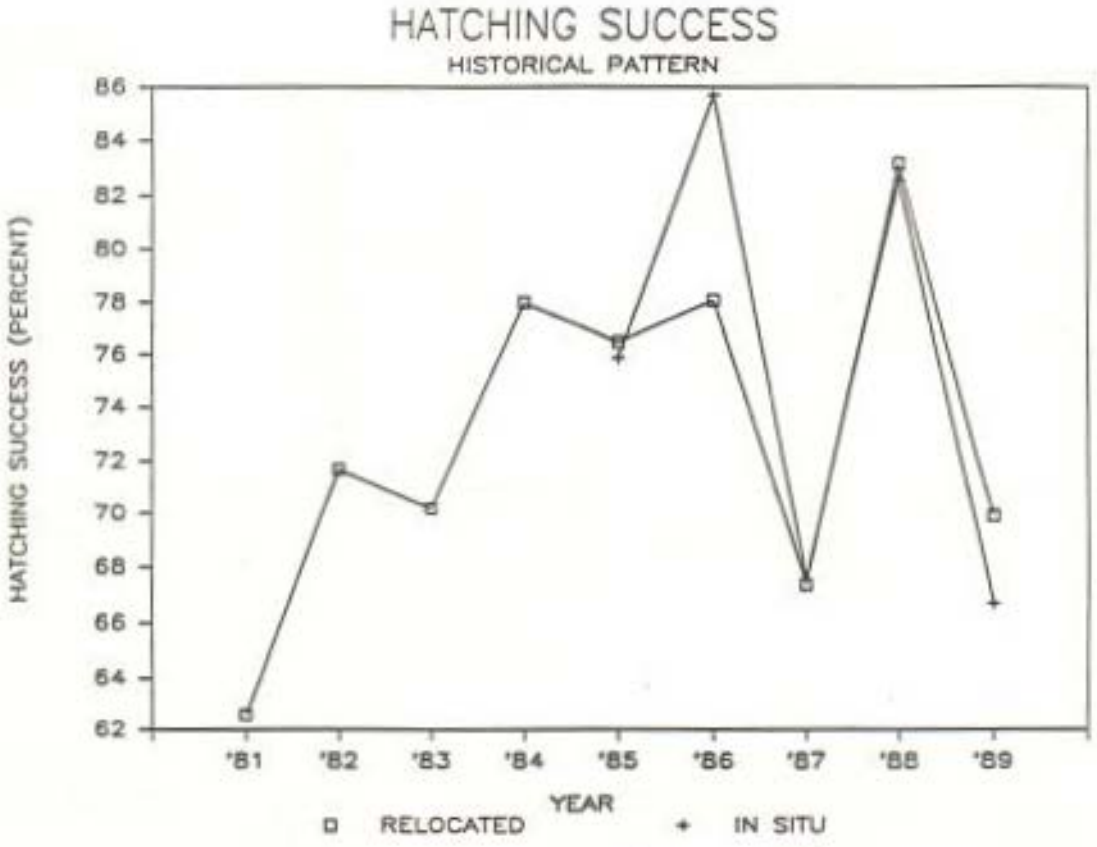

Figure 17: The historical patterns of yearly hatching success in relocated and in-situ (natural) nests since open beach hatcheries were first employed in 1981. Prior to 1981, relocated nests were hatched indoors.

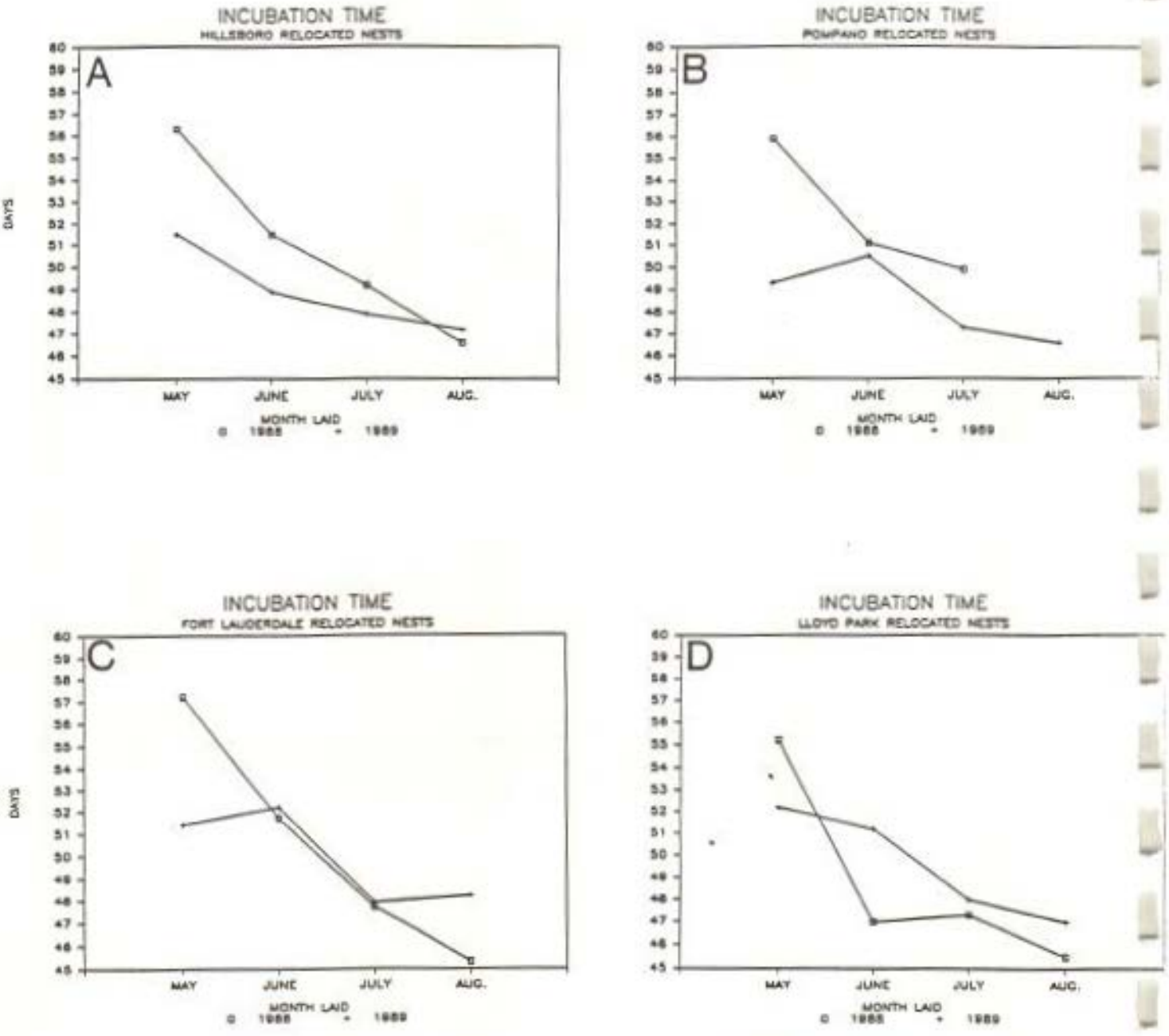

Figure 18: The patterns of monthly mean incubation times for relocated nests at Hillsboro (A), Pompano (B), North and South Fort Lauderdale (C) and John U. Lloyd State Park (D) beaches in 1988 and 1989.

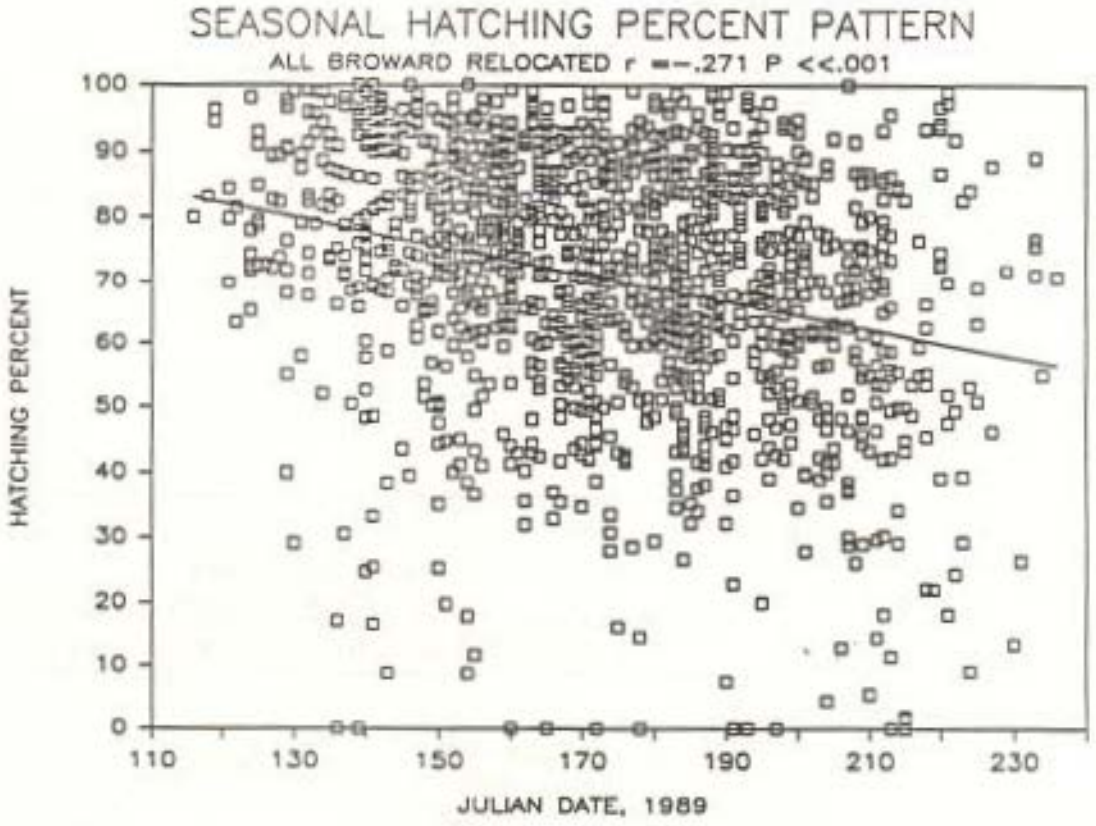

Figure 19: The County-wide seasonal trend in hatching success for all nests in 1989, with linear regression line, correlation coefficient (r) and significance level (P).

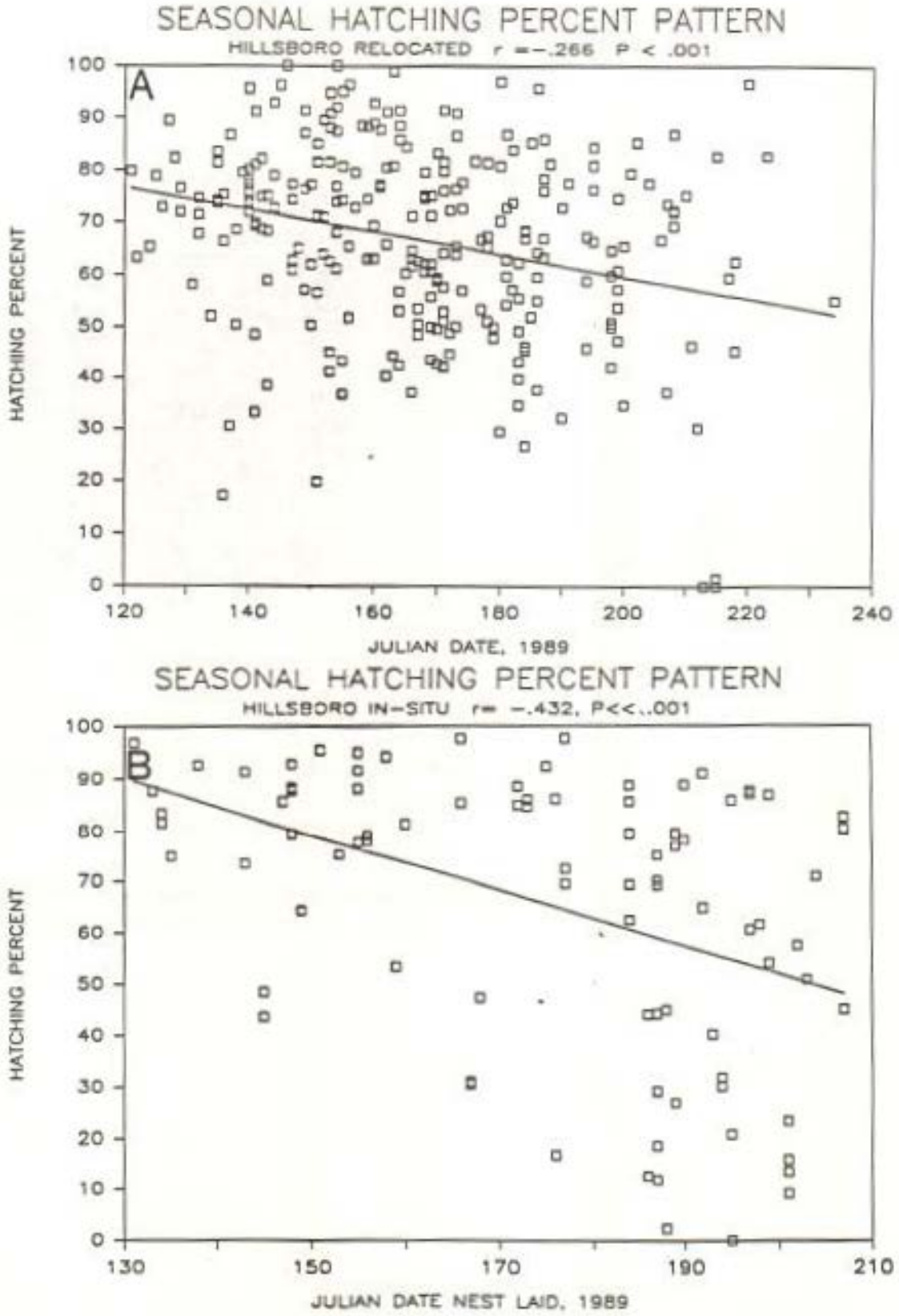

Figure 20: The seasonal trends in hatching success for relocated (A) and natural (B) nests at Hillsboro beach, with statistical parameters as in Figure 19.

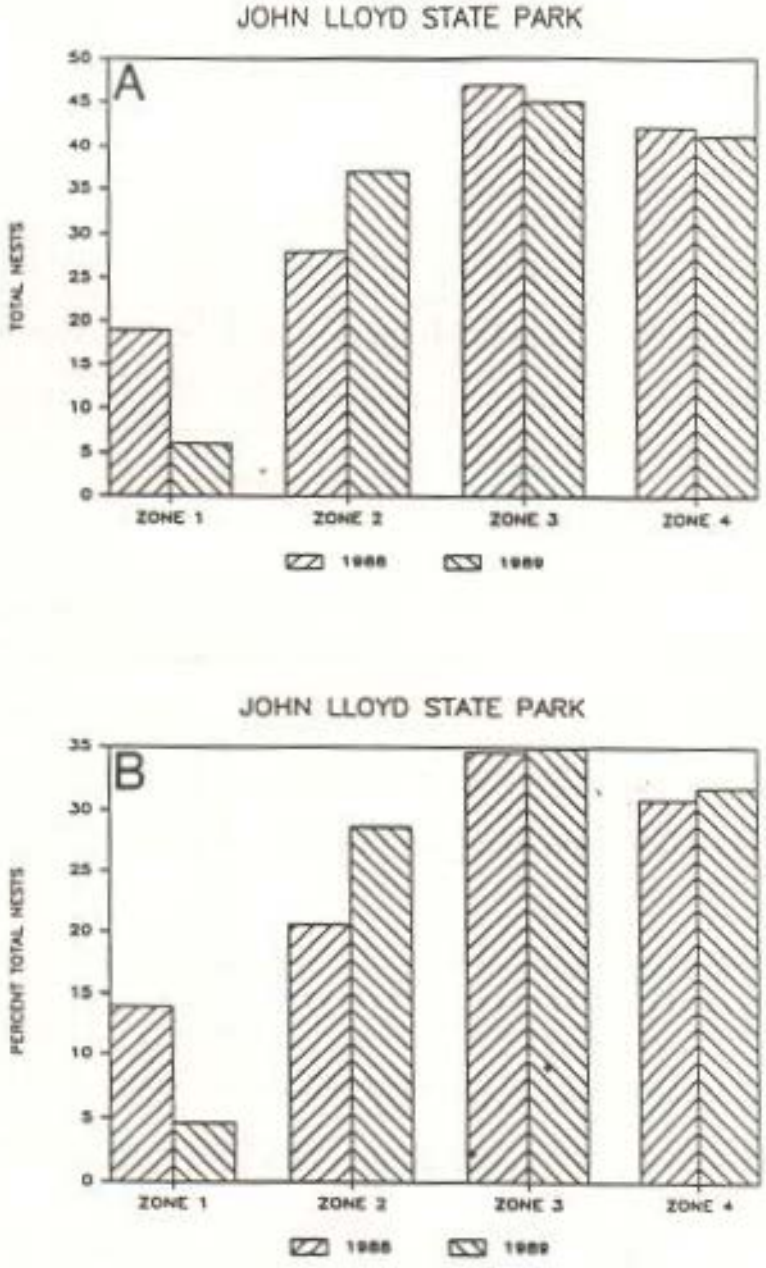

Figure 21: Comparison of total nests (A) and percent total nests (B) deposited in four 1 km zones on the beach at John Lloyd State Park during the 1988 (pre-renourishment) and 1989 (renourishment project in progress) seasons. Zone 1 is farthest north.

result from a predominantly three year nesting cycle in the population. Such a three year pattern would require most turtles to nest at a greater than three year interval (Frazer, 1989).

The historical patterns of nesting densities for *C. mydas* and *D. coriacea* (Fig. 2) show no long-term trends and considerable interannual variability. The apparent synchronous fluctuations in the nesting patterns of the two species since 1984 is interesting and unexplained. If real, it must be due to some environmental process or cue which affects both species but not *C. Caretta*, because 1986 and 1989 were peak nesting years for the latter species (Fig. 1).

Comparison of the 1988 and 1989 seasonal nesting patterns for *C. caretta* (Fig. 3A) indicates that the difference in overall nest counts (298 nests) did not occur because of higher nesting densities at mid season in 1989. Rather, in 1989, nesting frequency increased more rapidly during the upward phase of the seasonal cycle and the seasonal decline was delayed and more abrupt, relative to 1988. This is illustrated by the sharp increase in daily nesting from May 18-20 and the sharp decline from August 1-4 (Fig. 4). However, when the data in Figures 3A and 3B were expressed at percent total nests (not shown) a Chi-square goodness-of-fit test showed no significant difference, indicating that there is no evidence for variations in the overall shape of the seasonal patterns. Daily nesting patterns for the individual beaches (Figs. 5A-E) show similar seasonal patterns except at John Lloyd State Park where a beach renourishment project was in progress. Few generalizations can be made concerning seasonal nesting patterns of *C. mydas* (Fig 3B) beyond the total duration of nesting, because of the small number of data. This is even truer for *D. coriacea*.

When total nesting was normalized per kilometer of beach and compared by 1-way ANOVA and a SNK test (Table 1), Hollywood-Hallandale clearly was lowest and Hillsboro definitely highest in terms of mean daily nesting per

kilometer. Both these groups were statistically distinct from all the others. Lloyd park had the second lowest mean daily per-km nesting, but it was not statistically different from Fort Lauderdale North. Likewise, this parameter was not statistically separable between Ft. Lauderdale North and Pompano or between Pompano and Ft. Lauderdale South.

It is probable that the greater nesting densities on Hillsboro Beach are related to its predominately single family residential nature, with no public access, except in Deerfield Beach, and reduced beach-front lighting relative to other Broward beaches. Both sections of Fort Lauderdale beach have smaller areas of relatively dark, residential areas, but nesting was not statistically distinct from Pompano Beach, which has heavy development and pedestrian traffic. Lloyd Park beach has no coastal development and very low night pedestrian traffic, but was the site of a beach renourishment project. Nesting distributions at Lloyd Park and the possible effects of the renourishment project will be discussed separately. Development in the Hollywood-Hallandale area ranges from relatively low in Dania and North Hollywood to extensive in the remaining area.

The effects of beach development and human activities on *C. caretta* nesting densities are very difficult to generalize. While there seems to be some negative effect of beach front development on nesting at Hutchinson Island (Martin et al., 1989) and moving lights will frighten nesting females (Mortimer, 1981), stationary lights seems to have little effect on *C. Caretta* nesting (Mann, 1977; Ehrhart, 1979). Heavy nocturnal pedestrian traffic has an obvious negative effect on nesting (ie. zero nesting on Ft. Lauderdale beach on 4 July, Fig. 5C) but this effect is difficult to quantify. It is possible that something other than beach front development accounts for the differences in nesting densities observed. Similarly, the distribution of false crawls per km and the mean

number of false crawls per km per day (Table 2) were not statistically different except at Ft. Lauderdale North and Hollywood-Hallandale, where they were significantly fewer. The reason for this is unclear.

The County-wide and individual daily nesting success patterns (Figs 6 and 7A-E) show no seasonal trends. The more frequent occurrence of 100 percent success days in the County-wide data near the beginning and end of the season result from single successful crawls. A small flurry of false crawls occurred on all beaches except Hollywood-Hallandale in September, after successful nesting had virtually ceased (Figs 6 and 7A-D). This may indicate that other factors (possibly environmental), in addition to full oviducts, may play a role in initiating crawls. There were significant differences in mean daily nesting success between beaches (Table 3). Lloyd Park had the lowest nesting success. This may have been a result of ongoing beach renourishment, but mean nesting success at Lloyd Park was not statistically different from that at Pompano Beach. If nesting success was lower at Lloyd Park due to the renourishment project, the effect was no greater than may be caused by heavy beach development (Pompano). Nesting success at Hillsboro and both Fort Lauderdale sections were not statistically distinguishable, but it was statistically greater than at Lloyd Park and Pompano. The much higher nesting success at Hollywood-Hallandale was not included in this analysis, but these data would clearly be statistically distinct and the reason for such high success requires further study.

The trend of decreasing clutch size over the course of a season shown for *C. caretta* (Fig 8) has been reported previously (Caldwell, 1959; Lebuff and Beatty, 1971). It may represent depletion of the number of ova fated for enlargement in a nesting year. This declining trend was found in all beach areas and was highly significant at Pompano, Fort Lauderdale North and Lloyd Park (Fig 9). However, the trend was nonsignifi-

cant at Hillsboro, Fort Lauderdale South and Hollywood-Hallandale. Lack of a significant relationship is not surprising at the latter two locations because of the relatively lower number of nests, but it is surprising at Hillsboro. The significance of this is unknown, but a preliminary hypothesis might envision a healthier local nesting population displaying nesting site tenacity (Carr, 1975), perhaps with a more abundant food source, capable of sustaining egg production without a significant decline. The Hillsboro turtles did not produce significantly larger clutches than at Fort Lauderdale North or Hollywood-Hallandale (Table 4). The largest mean clutch sizes occurred at Hollywood-Hallandale, Lloyd Park and Fort Lauderdale South, which represented a statistically inseparable group. The mean clutch size at Pompano Beach was significantly smaller than at any other beach.

There appears to be a significant lunar periodicity in County-wide sea turtle nesting patterns (Fig. 10), superimposed on the seasonal trend indicated by the polynomial regression curve. Highest nesting densities corresponded to full or new moon periods (minima in the moon phase parameter) and fewer nests were deposited on both quarter moons. This trend was especially evident at Hillsboro Beach (Fig 11A) and less obvious at Pompano and Fort Lauderdale (Figs. 11B-C). A very similar pattern was found in 1988 nesting data from Hillsboro (not shown). It was less evident at Lloyd Park and nonexistent at Hollywood-Hallandale (Figs. 11D-E). County-wide, false crawls followed a similar pattern (Fig. 12). The moon effect was not evident during very early and very late season, but detrended average daily nesting during peak season (19 May to 6 Aug.) was strongly correlated with the moon phase parameter in for the combined date (Fig. 13) and at Hillsboro, Pompano and Fort Lauderdale (Fig. 14A-C). The relationship was barely significant at Lloyd Park and nonsignificant for Hollywood-Hallandale (Fig 14D-E).

It seems probable that the stronger relationship at Hillsboro must be related to the lower level of disturbing factors. Farther south, heavier development, lighting and general beach commotion may have disrupted the pattern. Since the relationship was weak very early and late in the season, this apparent periodicity may be more evident where a relatively stable nesting population of sufficient size exists. In Hollywood-Hallandale, the smaller nesting population may have been more vagrant in character, while the Hillsboro population may have displayed greater nesting site tenacity (Carr, 1975).

Lunar effects on nightly sea turtle nesting patterns have been previously reported (Talbert et al., 1980) but lunar periodicity was identified during only one year and the relationship was rather unconvincing. Unless turtles can sense gravitational anomalies, the effect of moon phase on nesting must be related to tides. Moon light is not the cue because the effect was similar on both the new and full moons. There is much confusion on the effects of tides on sea turtle nesting patterns. Some authors (Caldwell, 1959; Davis and Whiting, 1977) found no effect of tides, while Bustard (1979) and Frazer (1981) did. Others found tidal effects on some years and not others (Dean and Talbert, 1975; Talbert et al. 1980). Frazer (1983) found a statistically significant tendency for *C. caretta* to nest on high tides on Little Cumberland Island with a 2 m mean tide range, but no similar effect at Cape.Canaveral and Cape Lookout, with mean tidal ranges of 1.1 m. He proposed that *C. caretta* prefer to emerge at high tide on beaches with relatively higher tidal ranges, but not on ones with lower tidal amplitudes. We have found an association between daily County-wide nesting (3 point moving average) and the time of the nocturnal high tide (Fig. 15). There seemed to be a nesting preference when high tides occurred between dusk and midnight. The correlation of the height of the nocturnal high tide with the smoothed daily nesting data was significant at Hillsboro, Fort Lauderdale and County-wide, but when both time and height

of the nocturnal high tide were used to predict nesting patterns, high tide height was always a nonsignificant addition to the step-wise multiple regressions. A complete analysis of the effect of tide heights, times and ranges on nesting patterns is in progress and will be published separately.

From a management perspective, the relationship of moon phase and sea turtle nesting densities may be more useful than a tidal relationship since moon phase is easier to follow (especially for workers on the beach before dawn) than a more esoteric multiparameter tidal relationship. Coordinators or future Broward projects should be aware of (or at least not surprised by) heavier nesting near new and full moons, and allocate personnel and equipment resources accordingly.

A total of 1392 nests (82.1 percent of total nests) were relocated to hatcheries or safer beach locations. Most of the relocations were due to beach lighting which would disorient hatchlings. A total of 151,952 eggs were relocated and 104,622 hatchlings were released. This represents an increase of 41 percent over the number of hatchlings released in 1988. With only one exception, there has been an increasing number of hatchlings released each year since 1978 (Fig. 16).The 69.9 percent hatching success (Table 5) compares favorably to the 66.7 percent success for natural nests (Table 6). Hatch success for *C. mydas* and *D. coriacea* (Table 7) were similar, but based on limited data. Clearly, hatching success for both relocated and natural nests was down from 1988, but it was similar to several other years since hatchery operations commenced in 1981 (Fig. 17). The source of the great interannual variability is unknown, but maybe related to weather conditions. The summer of 1989 was unusually dry and hot. A comparison of average monthly incubation times for relocated nests (Fig. 18) for 1988 and 1989 shows that eggs laid in May hatched faster in 1989 than the previous year. Warmer sand temperatures are

probably responsible since this is the usual explanation for the seasonal decline in incubation times. At Hillsboro and Pompano (Fig. 18A-B) hatching times in 1989 were always lower or virtually identical to those in 1988. The patterns were more confused at Fort Lauderdale and Lloyd Park but shorter incubation times are suggestive of warmer egg chamber temperatures, especially early in the season. This may have contributed to the lower hatching success in 1989.

Hatching success also declined seasonally (Fig. 19). This may have been due to higher egg chamber temperatures later in the season which may have adversely affected development. More speculatively, it may also have resulted from a seasonal decline in egg quality or viability or to more ineffective matings later in the season.

A comparison of seasonal hatching success patterns in relocated and natural nests (Fig 20) show similar trends. It would ordinarily be useful to statistically compare the slopes of the trend lines in Figures 20A and 20B to determine if the seasonal decline in hatching success occurred more rapidly in natural or relocated nests. This was not done because many more late-season natural nests were investigated. This could bias any conclusions.

The comparison of total sea turtle nesting in the four zones at John Lloyd State Park in 1988 and 1989, expressed as total nests and percent total nests, show little difference (Fig. 21). In 1988, nesting in Zone 1 (north end of park) was reduced, due to a 4-5 ft vertical eroded beach cliff. In 1989, this area was heavily impacted by the renourishment project. Comparison of monthly nesting patterns in 1988 (Fig. 22A) show that turtles preferred the southern half of the park, where erosion was slight or nonexistent. In 1989, beach renourishment commenced on May 16, and ended July 14, proceeding from Zone 1 to Zone 3. Zone 4 was not affected. Figure 22B shows that only three turtles nested in Zone 1 in July, long after the project was finished in

this area. Likewise, July nesting was lower in Zones 2 and 3 relative to Zone 4. Surprisingly, June nesting was higher in Zone 2 during the time that the project was in this section.

Clearly, the renourishment project did not catastrophically impact sea turtle nesting in the park. A total nesting success of 42.3 percent (Table 3) compares favorably with 35 percent in 1988 (Broward Co. Erosion Prevention District, 1988). It is likely that the pumping out phase of such a project will deter turtles from emerging when it occurs at night. The cycle of a beach renourishment operation alternates between offshore dredging and pumping and distribution of sand on the beach. The latter operations are extremely noisy and well lit at night and almost certainly persuades turtles not to emerge. Nova personnel were on 24 hour call to relocate nests and move nesting females in the path of the renourishment operation and no calls were received. During dredging cycles or when pump out occurred during daylight, turtles were free to use the beach. The low July nesting activity in Zones 1 and 2 (after renourishment) suggests that the turtles initially avoided the new sand. Since it is known that sand characteristics have little effect on site selection as long as it is not to hard or rocky to prevent digging (Hughes, 1974), it is unlikely that the grain size distribution, water content, etc. was responsible. It is known that offshore beach contours can affect beach selection (Mortimer, 1981). It is possible that turtles rejected the new sand due to changes in the offshore profile. This effect would only be temporary, as wave action will restore a more natural profile (certainly by the 1990 season). Turtles dissuaded from nesting at Lloyd park almost certainly nested elsewhere. We have no compelling evidence of any long-term effect on nesting patterns. An analysis of this question will require 1990 data.

CONCLUSIONS

1) There has been an upward trend in sea turtle nesting densities in Broward County since 1981. While the trend is hopeful, it is statistically significant at only the .063 level (93.7% confidence level).

2) There have been no detectable long-term trends in the nesting densities of *C. mydas* or *D. coriacea*, however there have been large interannual fluctuations.

3) There is no statistical difference in the County-wide seasonal distribution of *C. caretta* nesting between 1988 and 1989, however nesting densities increased more rapidly and declined later and more sharply in 1989 than in 1988.

4) There are significant differences in sea turtle nesting densities per kilometer between the Broward Co. beaches, with Hillsboro significantly higher and Hollywood-Hallandale significantly lower than any other beach. Nesting densities at other beaches could not be statistically distinguished (not significantly different).

5) False crawls per kilometer were significantly fewer at Ft. Lauderdale North, far fewer at Hollywood-Hallandale, and statistically indistinguishable elsewhere.

6) There is no seasonal pattern in nesting success on any Broward beach but there are differences between beaches, with Hillsboro and Fort Lauderdale significantly greater and Lloyd Park and Pompano significantly less.

7) Pompano beach nests had significantly smaller clutch sizes than the other beaches.

8) Overall, *C. caretta* fecundity (eggs/clutch) and hatching success declined with time during the nesting season.

9) There is a significant County-wide trend of heavier nesting and false crawling near the times of new and full moons and fewer nesting and false emergences near quarter moons. This is probably related to the lunar effect on tides.

10) The significant correlation of nesting with an independent variable such as moon phase indicates that this project gathered good scientific data.

11) There were 30,663 more hatchlings (41%) released from relocated nests in 1989 than in 1988. 82.1% of all nests in Broward Co. were relocated, mostly because of artificial beach lighting.

12) Although hatching success was down compared to 1988, it was not historically aberrant. There is no evidence that relocated nests or hatchery operations adversely affected hatching success.

13) A beach renourishment project did not profoundly affect turtle nesting. There may have been some temporary effects during and immediately following the project, but we have no evidence of any long term effects.

RECOMMENDATIONS FOR FUTURE PROJECTS

Based on our experience this year, we offer the following operational suggestions to improve the efficiency of future projects. We realize that fiscal restraints may intervene. The following will speed future projects which may possibly require fewer personnel due to increased operational efficiency.

1) Assigning more personnel to beaches to help relocate large numbers of nests is inefficient if they do not have vehicles. There should be at least one extra ATV and a small trailer so that extra vehicles could be put in service and relocated as needed.

2) ATVs on heavily nested beaches should be fitted with flat bed trailers capable of holding at least 8 nest buckets, in addition to those already carried. This would usually allow all nests to be collected in one pass of the beach and would eliminate the multiple trips necessary this year. This would greatly speed operations.

3) Survey crews on the heavily nested beaches should have portable communications. Small, relatively inexpensive portable CB radios would suffice. While these do not have cross-County range, the project manager could communicate with workers while driving down A1A. It is also possible that workers could relay messages from more distant beaches. Such communications would also make it easy for helpers to locate the survey crews on the beaches.

4) Due to the new beach lighting requirements (relocate all nests from areas where you can see your shadow on the beach at night), more hatcheries must be built, or present ones enlarged. The former would be preferable since hatcheries distributed along the beach would cut travel time. Hatcheries should be located away from vegetation, to reduce invasion by ants.

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APPENDIX 1: SUMMARY OF SEA TURTLE HOT-LINE AND SEA TURTLE BEEPER CALLS

MAY 01 THROUGH SEPTEMBER 15

SUBJECT OF CALL	HB/DFB	POMP	FTL N&S	JUL	HWD/HA	GENERAL
NESTING TURTLE	3	9	44			
STRANDED TURTLE	1	3	1			
EMERGING HATCHLINGS		4	6	4		
DISORIENTED HATCHLINGS		3	3			
NEST LOCATIONS	10	33	39			
POACHING						
SEA TURTLES INFO						47
ADOPT-A-NEST INFO						3
TURTLE WALK INFO						9
VOLUNTEERS						82
DREDGING CO.						

APPENDIX 2: **Summary of Educational/Public Information Activities**

Twelve hundred turtle flyers were published and distributed in a timely manner along the beach, mostly to people who approached workers with questions and at the night turtle releases at Pompano and Fort Lauderdale, which usually attracted crowds. Flyers were also placed in beach-front business establishments and some were distributed to people touring the Oceanographic Center. Forty seven calls for general turtle information were received and answered on the turtle hotline. Either the principle investigator or project manager gave a total of turtle talks at three elementary schools and one public library.

Project personnel operated a booth at the eleven-day Broward County Fair (Nov. 16-26) as part of the Environmental Expo, with a display of live hatchlings and stuffed and preserved specimens. The display generated considerable interest. Several hundred more flyers and other turtle brochures were distributed and innumerable questions were answered.

1989 ST Rpt.

FLORIDA DEPARTMENT OF NATURAL RESOURCES
MARINE TURTLE NESTING SUMMARY REPORT FOR YEAR 1989

This form must be typed or printed legibly in ink and signed.

Turtle Permit Number (TP#): 129
Principal Permit Holder: Louis E Fisher
Organization: Broward County Erosion Prevention District - EQCB
Address: 609 B SW 1st Avenue
Ft Lauderdale, FL 33301
County: Broward
Telephone: (day) 305 765 4013 (evening) 305 429 9248

Beach Name: Broward County
Beach Length: 38.6 kilometers km / mi (circle unit)
County: Broward
Start Date of Patrol: 1 February 89
End Date of Patrol: 15 September 89
Number of Days Per Week Patrolled: seven (7)

NESTING SUMMARY TABLE	CC	CM	DC	UNKNOWN
Total # of false crawls	1379	15	2	
Total # of nests	1670	21	4	
Date of first nest	4/20/89	6/2/89	4/24/89	
Date of last nest	9/8/89	8/17/89	5/19/89	
HATCHERY DATA:				
Total # of nests in hatchery	754	10	1	
Total # of eggs in hatchery	83,908	1,305	105	
Total # of live hatchlings	61,114	997	62	
BEACH RELOCATION DATA:				
Total # of nests relocated	625	2	1	
Total # of eggs relocated	66,634	232	145	
Total # of relocated nests screened				
Total # of live hatchlings	42,087	135	99	
IN SITU DATA:				
Total # of in situ nests screened				
ARTIFICIAL INCUBATION DATA:				
Total # of nests incubated				
Total # of eggs incubated				
Total # of live hatchlings				

NOTE: Hatchery = permanent fenced area where nests are reburied and concentrated in a group
Relocated = nest reburied at a different site on the beach, not in a hatchery
In Situ = natural nest left in place where deposited
Incubated = eggs transferred from natural nest to a permanent artificial container (styrofoam cooler, bucket, etc.)
Screened = protective flat screening or portable cage screening placed over nest

COMPLETE THE BACK OF THIS FORM ALSO

1989 NESTING SUMMARY REPORT CONTINUED

Type of hatchery utilized: self-releasing restraining (circle one)

Reason hatchery was utilized: protection of relocated nests. Nests at John U. Lloyd Park were in a self-releasing hatchery. Hatcheries at Hollywood, Ft Lauderdale and Pompano Beach are retaining hatcheries

Reason nests were relocated: Nests were relocated primarily due to artificial lighting on the beach. Nests at John U. Lloyd Park were relocated due to a beach renourishment project at the Park.

Reason nests were artificially incubated: _____

Predators (type and number of nests affected if known): 4 nests at Lloyd park were destroyed by racoons

Describe predator control methods employed (if any): approximately 12 nests at Lloyd Park were screened they were all Caretta

DATA ON EXCAVATED in situ NESTS:	CC	CM	DC
No of nests examined after hatch	95	3	1
Total no. of eggs	10,146	317	136
Total No. of Hatchlings calculated	6,766	218	90

I certify the above information to be true and accurate to the best of my knowledge.

Signature of Principal Permit Holder — Date: 8 December 1989

This public document was promulgated at a cost of $452.46, or $1.810 per copy to provide information about the Sea Turtle Conservation Project.

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