BREEDING ECOLOGY OF CATTLE EGRETS AND SNOWY EGRETS AT THE SALTON SEA, SOUTHERN CALIFORNIA

A Thesis

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by

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INTRODUCTION

The potential or actual ability of an organism to extend its distributional range is central to several important biological concepts such as evolution and speciation, community structure and function, and population interactions. MacArthur and Wilson (1967) recently attempted to integrate some of these concepts into a coherent and usable theory, an effort that has met with at least a moderate degree of success. The mechanisms by which a successful range extension occurs are poorly understood, although such understanding is essential to man's successful prevention, control, or utilization of species eruptions, of which he is often a powerful and unwitting instigator (Elton 1958).

Examples of organisms which are undergoing active range expansion tend to be uncommon, and those which are doing so without having been introduced into a new locality by man are rarer yet. Prior to the late 18th century, the Cattle Egret, *Bubulcus ibis* Linnaeus (Ciconiformes, Ardeidae), was distributed throughout southern Portugal and southern Spain, eastern Turkey, the Caspian Sea, Iran, India, Burma, southern China, Ceylon, Java, Bali, and central Africa (A.O.U. 1957).

Since then, it has undergone an explosive range expansion, entering South Africa in the late 1920's and early 1930's (Siegfried 1965 and 1966c), Australia in 1948 (Skead 1956), and the New World in the vicinity of Surinam about 1888 (Haverschmidt 1957, Weber 1972). The species has subsequently spread southward in South America, and in 1974, a Cattle Egret was sighted as far south as Rio Grande do Sul, Brazil (Belton 1974). It is the African form of the Cattle Egret, *B. i. ibis*, and not the Indian form, *B. i. coromandus*, which is present in the New World (Sprunt 1955).

The Cattle Egret was first seen in North America about 1941 and established a breeding colony shortly thereafter in Florida (Sprunt 1955). In 1952, after spreading northward across the United States, Cattle Egrets were sighted in Newfoundland, and a breeding colony was established in Ontario, Canada, in 1962 (Kuyt 1972). Cattle Egrets also appeared in the southern and western United States and in Mexico, although it is unclear whether or not the species had expanded westward across the United States or northward from Central America, perhaps along the Pacific coast. Guy McCaskie (personal communication) first noted the species breeding in the Imperial Valley, southern California, in

July 1969, at the New River delta on the Salton Sea. This colony is the one which I studied intensively in 1974.

This colony also contained breeding Snowy Egrets, *Egretta thula* (Molina). The Snowy Egret is similar in size and general appearance to the Cattle Egret, but it feeds almost exclusively in aquatic habitats, unlike the Cattle Egret. It offered a convenient opportunity to make comparisons between a long established species and a rapidly expanding, colonizing one with specific regard to timing and success of the breeding season, as well as other aspects of their life history. Snowy Egrets range from northern California, southeastern Idaho, Colorado, central Oklahoma, the Gulf coast of the United States, and New Jersey south locally through Central America, the West Indies, and South America to central Chile and Argentina (A.O.U. 1957). The western subspecies, *E. t. brewsteri* (Thayer and Bangs), was the form present in the breeding colony at the Salton Sea.

During the 1974 breeding season, reproductive effort and success were determined and compared for both Cattle and Snowy Egrets breeding together within the same colonies located in the New River delta, Salton

Sea. Reproductive parameters examined were: size of breeding population; timing of various nest events such as initiation, hatching, and fledging; eggs and nestling mortality; eggshell thickness and pesticide levels present within the eggs; and nestling food habits.

MATERIAL AND METHODS

Study Sites

The Salton Sea is located in hot, arid country that was formerly desert. During summer, daytime temperatures often reach 49°C. Because of its location and lack of outflow, the Salton Sea has a salinity concentration many times that found in the open ocean.

The New River flows into the southern end of the Salton Sea, forming a large, brushy delta. The two breeding colonies of Cattle Egrets and Snowy Egrets are located on the periphery of this delta (Fig. 1). In one colony site, which I named the Old Colony, various species of egrets and herons have been known to breed occasionally for many years. This site is about 2,420 m from the shore and occupies the middle of a long, brushy stand of dead trees stretching northwestward from the delta. These trees stand in water ranging in depth from about 1 m at the southeast to about 3.5 m at the northwest end, and are roughly arranged in rows, possibly as an artifact resulting from an old and now submerged system of roads and ditches. All aspects of this colony are exposed to the full force of the wind,

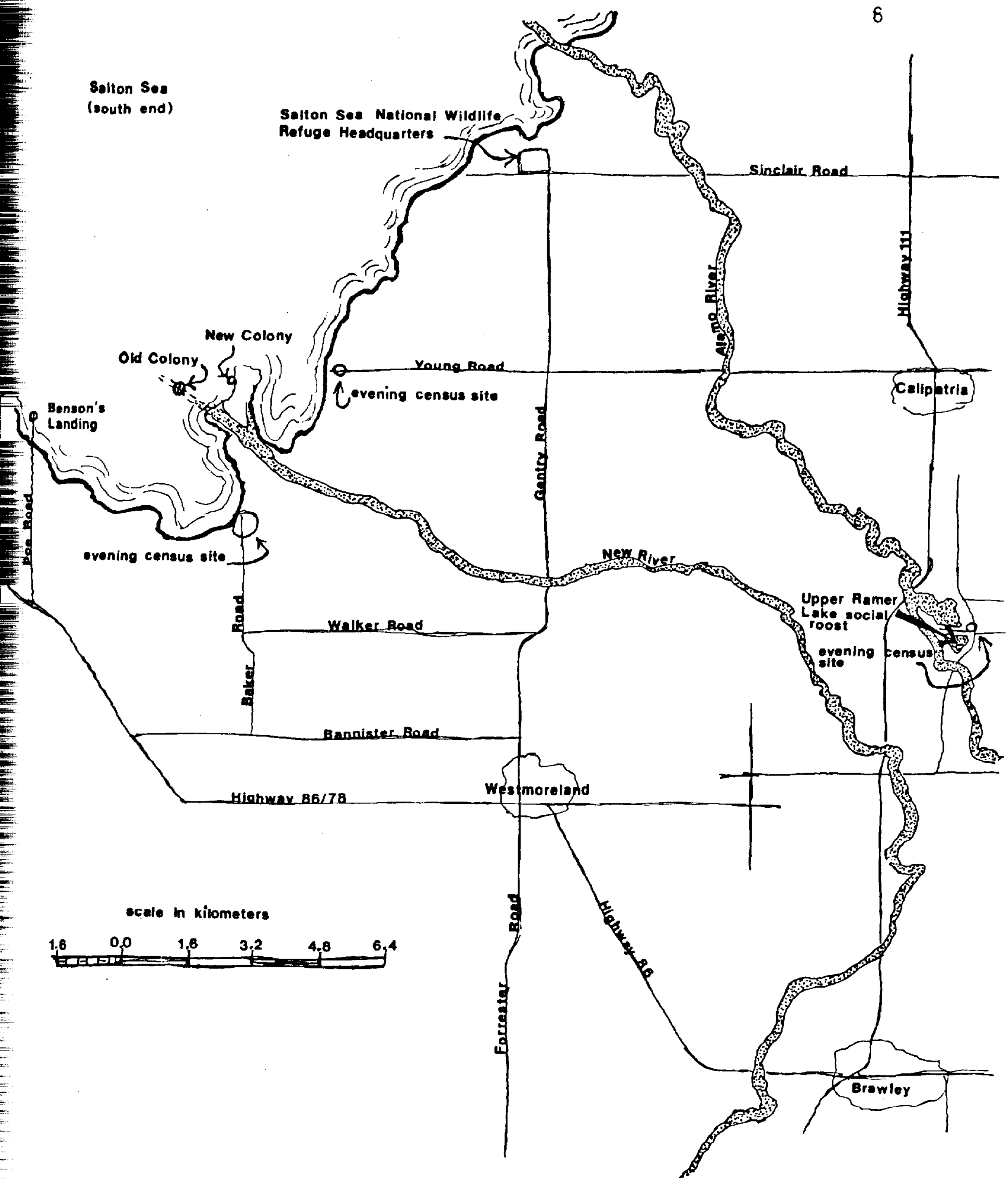

FIG. 1. *Map showing the location of both breeding colonies in the New River delta, the Upper Ramer Lake social roost, and the evening census sites.*

but it is also far enough from the shore that mammalian predators have not been known to exploit it.

The New Colony, so named because it was established during the 1974 breeding season and, as far as is known, had never been used before, stands on the exposed, west side of the northernmost tip of the main delta. In this colony, nests were located in large dead trees and areas of thick, dead brush, which were located partly in shallow water and partly on shoreline areas with a substrate of mud or barnacle shells.

The trees and brush used for nesting in both colonies had been dead long enough that they could not be identified. Nest twigs were collected both within the colonies and in other areas of the delta. Occasionally nest twigs with green leaves were seen; these appeared to be tamarisk, *Tamarix* sp.

The Ramer-Finney Lake area is located on the Alamo River between Calipatria and Brawley (Fig. 1) and is about 21 km southeast of the New River delta. Ramer Lake is divided into upper and lower portions by an east/west dike. The social roost for most Cattle Egrets and a few Snowy Egrets is located at the northeastern edge of Upper Ramer Lake in dead trees and brush which extend into the lake. This area is subject to human disturbance from fishermen, dove hunters, and other intruders.

Colony Visits

Because of the location and nature of the study area, a boat was necessary to collect almost all data. A 4.3 m Boston Whaler with either a 10 or a 15 horsepower Johnson outboard motor was launched from Benson's landing at the south end of the Salton Sea. At the beginning of the study the motor was used occasionally within the Old Colony as the first nests tended to be located in small, clumped areas that were far apart. Later, when nests were spaced much closer together, the boat was paddled through the colony to reduce disturbance. At the beginning of the season when the weather was cool, visits to the colony were made mostly in the afternoon. Strong winds during the morning hours often made the water too rough for boat activity at this season. Later, as the temperature rose, the pattern switched and the wind tended to blow in the afternoon, not at all, or at unpredictable times and velocities throughout the day. After this weather change, I visited the colonies at dawn, usually arriving by 0600. All nest checking activity was halted by 0830 to 1000.

By these times, temperatures had risen to the point that unshaded eggs or nestlings were in possible danger from overheating.

From mid-March to mid-May, due to university commitments, colony visits were scheduled on two weekend days. After mid-May, colony visits were scheduled every three days. Due to time limitations, and to minimize disturbance, I usually checked only half of the Old Colony on a single visit. Two consecutive visits were thus required to completely survey this colony. Because of its smaller size, tightly packed nesting structure, and shallow water, the New Colony could usually be completely checked in a single visit. A rigid schedule of visits was impossible because scheduled visits were often shortened, modified, or completely prevented by unpredictable and violent winds. These winds could cause highly dangerous boating conditions on the Salton Sea at any time.

An attempt was made to check an adequate sample of from 25 to 75 active nests in each row of the Old Colony, including the section where two rows merge into one. In the New Colony, nests were sampled throughout the entire colony with two exceptions: the extreme eastern section where the soft mud bottom was too deep for safety (these nests later vanished) and the extreme southwestern edge, where it would have taken too long to check the few nests present. Because of the necessity for speed, all observations and data were recorded on a small cassette tape recorder and later transcribed into notebooks.

Population Counts

Estimates of the total Cattle and Snowy Egret population were obtained by summing counts of birds present in the breeding colonies during the day, those flying in to roost at night in the colonies, and those flying in to roost for the night at Upper Ramer Lake. Specific counting sites for egrets flying into the breeding colonies were located in the New River delta at the north end of Baker Road and the west end of Young Road (Fig. 1). Egrets flying into Ramer Lake were counted either from the railroad tracks northeast of the Upper Lake, or from the dividing road between Upper and Lower Ramer Lake (Fig. 1). Estimates were made by using 7 x 35 or 10 x 50 binoculars and either counting each bird, or estimating units of 5, 10 or 100 birds, depending upon the size of the flock. Each evening count was begun at least 1 h before sunset and was terminated either when it was too dark or when no egrets had been seen for at least 30 min after sunset. In poor light or at great distances, it was very difficult to separate Cattle Egrets from Snowy Egrets in the air. Because approximately 80 to 90% of the birds flying in to roost were Cattle Egrets, and the flight paths in from fields (Cattle Egret feeding habitat) were generally different from those from the marshland feeding grounds of Snowy Egrets, any given egret flying in from a field direction was assumed to be a Cattle Egret unless positively identified as a Snowy Egret.

In the nesting colonies, after all nest data had been taken, counts of birds present were made by stationing the boat 8 to 23 m away from the nearest nest, then counting all adult and juvenile egrets of both species. The boat was quietly moved by paddling when necessary to keep birds within the binocular range at which the species could be readily identified. Plumage characteristics of Cattle Egrets have been described by Siegfried (1971c) and Foster and Tiller (1973), and of Snowy Egrets by Meyerriecks (1960).

Nest Data

Prior to the start of the breeding season, all old nests still present in the Old Colony were marked by tying colored surveyor's plastic tape around the supporting branch or trunk directly beneath the nest. The first few nests to have eggs were also marked with surveyor's tape as a navigational aid before the colony's topography was memorized. Each nest was tagged with a numbered wooden tag tied directly beneath, or next to the nest with nylon cord. An attempt was made to use a different color and range of numbers for Snowy Egret nests. This effort was abandoned when it became apparent during the course of the season that particular nest sites often changed species from nesting attempt to nesting attempt.

Each egg within a tagged nest was marked, by using waterproof Koh-I-Noor drawing ink and a Rapidograph pen, with a simple code for the day and month on which it was first seen. Any damage to the egg's surface was recorded as a dent, crush mark, or a hole. Damage that consisted of sharp, clean cracks with relatively large pieces of shell pushed inward were considered dents. Crush marks were areas wherein the shell had been pulverized into many small pieces and were either pushed inward, or would easily move in at the touch of a finger and bounce back out, as if the egg were a rubber ball. A hole was any damage that had actually gone through both the shell and membranes. Any tagged nest with egg white, yolk, or bits of shell in the bottom was noted.

Eggs were recorded by their code; nestlings were counted and notes on feather development were made. An egg was recorded as pipping if a hole was present and a developed embryo could be seen. It was recorded as alive only if the egg chirped when held up to an ear and tapped with a finger. Any nestling found with wet or damp down was recorded as newly hatched. Nestlings retained dry, fluffy down until about five days old, when pinfeathers usually became apparent. A nestling was termed a "brancher" when its pinfeathers had almost completely opened so that it presented a well-feathered appearance. At this stage, and somewhat earlier, the young egrets were very active and quite capable of leaving the nest and traveling about the colony, using their long toes and bill for grasping branches. Although the young did not normally take to the water, those older than 7 to 10 days were surprisingly good swimmers, and would often leap into the water and paddle away when stressed. For each brancher, there was a period of approximately 2 to 4 weeks, depending on the age at which the young left the nest, during which it was still very much dependent upon its parents for food. It was still acquiring feathers, muscles, and flight skill, but during this time span I could not be sure of seeing it at the nest. Therefore, 14 days was arbitrarily decided upon as the minimum age a nestling had to have attained upon the last sighting to be considered as having survived to fledging for data analysis.

Young Cattle Egrets, like many other young herons and egrets, will readily regurgitate their last meal when disturbed or alarmed. All undigested foor boluses that were regurgitated while nests were being checked in both breeding colonies were collected and preserved in a 10% formalin solution. Later they were sorted and identified by David Foster, Los Angeles County Nature Centers, Pasadena, California.

When it was necessary to test for differences between means in evaluating or comparing data on reproductive effort, Bartlett's test for homogeneity of variances was applied first. If the variances were equal, a Student's t-test of the difference between two means was used; if variances were not equal, the nonparametric Wilcoxon's two sample test was used. A chi-square test for goodness of fit differentiated between the shapes of various distributions, while the test for the equality of two percentages evaluated differences between two quantities expressed as percentages. These statistical tests were obtained from Sokal and Rolf (1969), and used with the statistical tables from Rolf and Sokal (1969). Unless stated otherwise, the results of all statistical tests are reported at a significance level of $P \leq 0.05$. Data on reproductive effort are presented whenever possible as means ± standard deviations.

An estimated three quarters of all nests in the New Colony failed, including all of the tagged nests. A large proportion of the nesting failures were due to predation that started in the week of 30 June to 6 July. The predator was never positively identified as the nearest dry land was a barnacle shell beach, which did not retain tracks, and the live trapping effort occurred too late. The predator was inferred to be one or more raccoons from the condition of the carcasses and knowledge of the species present in the New River delta. As most of the nest trees stood in water, the predator was not bothered by water, was quite good at climbing trees, and was heavy enough to occasionally break branches. The many nest failures prevented extensive comparison of the Old and New Colonies. Unless stated otherwise, all results presented pertain only to the Old Colony.

Weather Data

General weather conditions were recorded for days on which colony visits were made. Detailed weather data for 1974 were obtained from Robert D. LeMert, Agricultural Research Technician at the Imperial Valley Conservation Research Center in Brawley. Brawley is located 31.5 km southeast of the New River delta.

An index of wind intensity was calculated from general wind data for the weekly periods during which I did fieldwork. In conjunction with data on average wind movement per week from the Brawley weather records, this index of wind intensity was compared to the timing of nest starts and nest failures. I had recorded wind intensity in three subjective categories: strong, medium to slight, and calm. The total hours of wind in each category was estimated for each week. The estimates were based on my notes and usual schedule so that all wind categories summed together equalled the total estimated hours during which I had been present in the area for a given week. To eliminate variability from my being present for unequal amounts of time per week, the index of wind intensity was obtained from dividing the estimated hours of strong wind per week by the total estimated hours I was present per week.

Eggshell Measurements

Organochlorine insecticides such as DDT were first used extensively about 1945 (Keith 1970, Ratcliffe 1970), thus eggs laid before or during the early 1940's should be free of DDT effects. Klaas et al. (1974) concluded in a study of variability in eggshell thickness and sampling, that in order to detect a true difference of 10% in shell thickness, at $P \leq 0.05$, a minimum sample size of from 8 to 11 whole clutches is necessary.

The Museum of the Western Foundation of Vertebrate Zoology, Los Angeles, has 40 clutches, totalling 179 eggs, of the Snowy Egret (*brewsteri* subspecies) collected from 1906 to 1953 with large enough collector's holes to permit measuring eggshell thickness. Only six clutches, totalling 23 eggs, had been collected after 1944 and the mean shell thickness of these eggs was not less than the mean shell thickness of all the eggs collected before 1944. Eight of the Snowy Egret clutches were collected in California; 5 were collected in Baja California, Mexico; 25 were collected in Utah; and 2 were collected in Nevada. Only 5 cattle Egret (*ibis* subspecies) clutches, totalling 20 eggs, collected prior to 1953 could be located. Three are held at the Museum of the Western Foundation of Vertebrate Zoology, and two additional clutches are at the San Bernardino County Museum. Two of the clutches were taken in 1918 in Spain, one was taken in 1930 in Uganda, one was taken in 1939 in Nigeria, and one was taken in 1952 in Spain. The shell thickness of the 1952 eggs was not less than that of the clutches collected earlier.

At the Salton Sea breeding colonies, some eggs of both species that were either hatched, broken, or floating in the water were collected.

All eggshell thicknesses were measured at the Museum of the Western Foundation of Vertebrate Zoology on a machine modified by Samuel Sumida for this purpose. The machine is a stand with a Miracle Movement P61 pressure-dial gauge, accurate to 0.01 mm, attached to a fixed upper arm. This gauge is attached to a slim bar of stout metal with a large sewing needle welded to it, eye-end down. The movable lower arm is a piston controlled by a knob and has a removable platform on top. A putty knife is taped to the knob to put a constant pressure against the dial gauge for ease in zeroing it. When measuring eggshell thickness, the base of the stand was tapped with a heavy metal object to ensure complete specimen settling. The machine's zero setting was checked every two or three eggs, and the dial gauge was read to 0.001 mm.

Nonoverlap of confidence limits indicates that differences between two means are significantly different (Steele and Torrie 1960). The significance of differences between museum eggshells and those collected at the Salton Sea was assessed by nonoverlap of 95% confidence limits.

Pesticide Residues

A number of Cattle and Snowy Egret eggs were frozen and sent to the Sacramento Pesticides Laboratory, California Department of Fish and Game, for pesticide-residue analysis. Two juvenile Cattle Egrets found dead in the colony were also sent to this laboratory. Their breast muscles were too small, so only brains and livers were analyzed for pesticide residues. Organochlorine insecticides are stored in lipids and are present in eggs almost entirely within the yolk, therefore ppm in yolk is the biologically accurate way of expressing residue concentration. However, to be comparable with other published values, data are also presented as ppm wet weight.

All statistical procedures follow Sokal and Rolf (1969), unless otherwise stated. Rankits, a graphical test for normality, was applied to the data. Eggshell thickness, percent damaged eggs per nest, and total eggs laid per nest were normally distributed, but a log transformation had to be applied to the pesticide residues. After this transformation, PCB residues were still only approximately normal and therefore a non-parametric statistic, Kendall's coefficient of rank correlation, was calculated for the log PCB and shell thickness. A parametric correlation was applied to all other data sets. Results of all tests are reported at a significance level of $P \leq 0.05$, unless noted otherwise, with $n = 26$ data pairs for the shell thickness and residue to residue correlations, and $n = 14$ data pairs for all other correlations.

Banding and Tagging

In 1973, a program of leg banding Cattle and Snowy Egrets in the Old Colony was begun by David W. Foster to obtain information on dispersal patterns, population age structure, and mortality rates. Eighteen juvenile Cattle Egrets were also experimentally tagged on the right wing in 1973 by attaching a square of lightweight, flexible, bright green plastic with a teflon bolt and nut through a small hole punched in the skin at the leading edge. The birds adjusted readily to the tag, which could be easily seen, and had no difficulty in flying with it. They appeared to be treated no differently than unmarked birds by other Cattle Egrets. Juvenile Cattle Egrets were wing tagged in 1974 on the right wing with squares of the same bright green plastic marked with a simple number and letter code by using black automotive-vinyl paint. These birds were also leg banded and had the left wing dyed yellow with picric acid dye. This dye became a strong orange brown after having been on the bird about 2 or 3 weeks. The color change was probably caused by the ultraviolent component of sunlight. Other juvenile Cattle Egrets were leg banded and had their left wing dyed yellow. Juvenile Snowy Egrets were captured and leg banded only. An attempt was made to capture and tag adult Cattle Egrets for observations on possible second nesting attempts. One of the few methods of capturing adult egrets is the use of mist nets with 12.8 cm mesh, and the net must be camouflaged by setting it up in front of a tall background. The only feasible place to mist net Cattle Egrets was at the west side of the New Colony. Only five adult Cattle Egrets were captured and tagged, as it proved impossible to easily capture large numbers of adult Cattle Egrets with minimum disturbance to the colony. Because of the technical difficulties, this part of the study was abandoned.

All banding and color marking or tagging activities were carried out with the full knowledge and express permission of the Bird Banding Laboratory, Migratory Bird Populations Station, in Laurel, Maryland.

RESULTS

Population Estimates

The evening population counts taken from the north end of Baker Road, the west end of Young Road, and at Ramer Lake were summed along with counts of egrets present in the colonies during the day to obtain total population estimates (Fig. 2). Estimated Cattle Egret populations were 2 to 12 times those of Snowy Egrets, and varied from 750 to 6,300 birds. Estimates of Snowy Egret populations ranged from less than 50 to about 500 individuals.

There was no really certain method of determining whether the egrets flying into the New River delta in the evening roosted in the New or Old Colony; therefore, the evening counts and the day counts for both colonies were combined. Increase in number of Cattle Egrets present in the colonies was paralleled by declining numbers of Cattle Egrets roosting at Ramer Lake (Fig. 3). When a population dip occurred during the week 12 to 18 May, a small population peak was observed at Ramer Lake. Although it is entirely possible that a few Snowy Egrets continually roosted at Ramer Lake among the Cattle Egrets, it was only rarely that Snowy Egrets

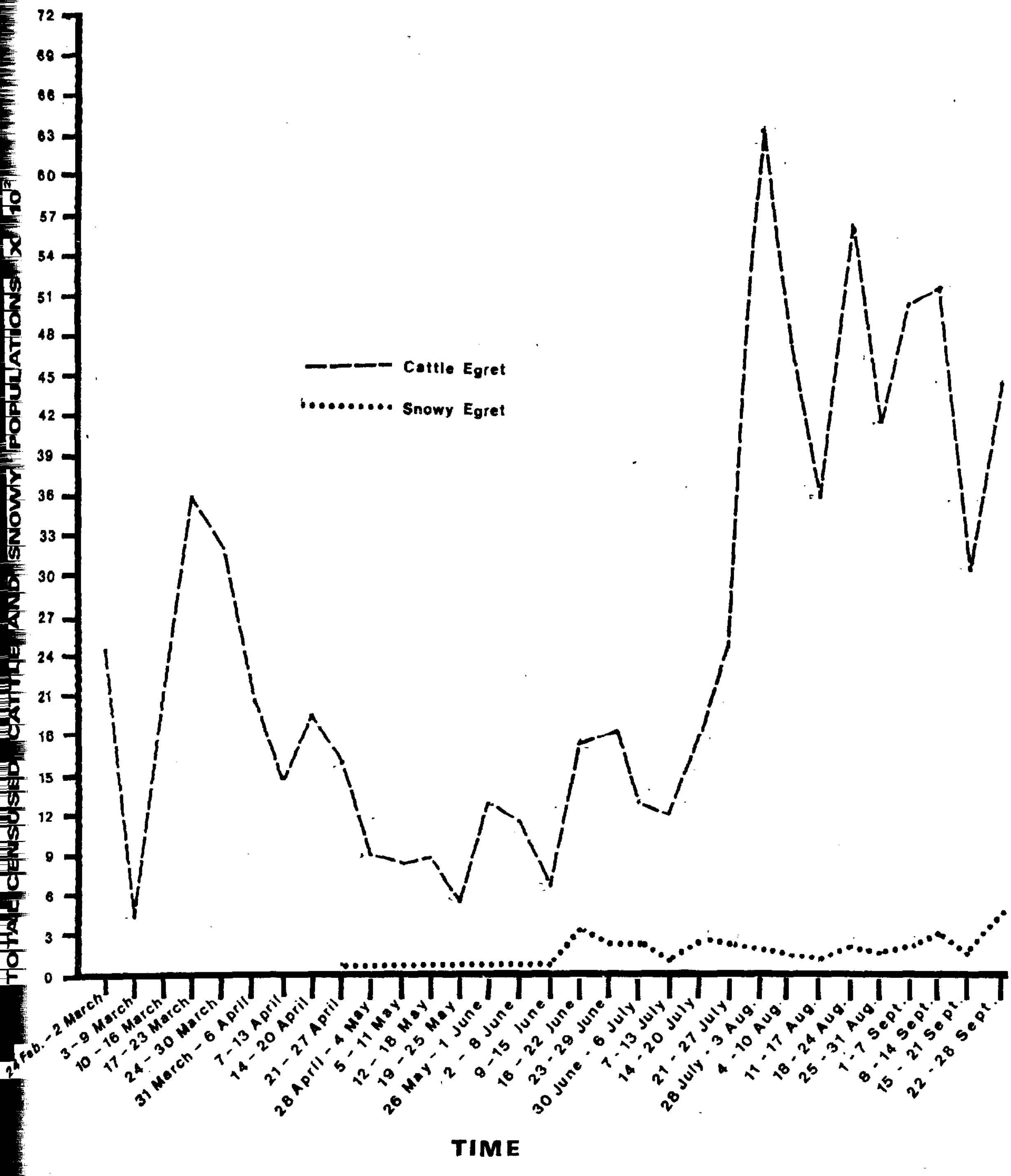

FIG. 2. *The total censused populations of Cattle Egrets and Snowy Egrets. Counts from Ramer Lake, the north end of Baker Road, the west end of Young Road, and both Old and New Colonies are combined.*

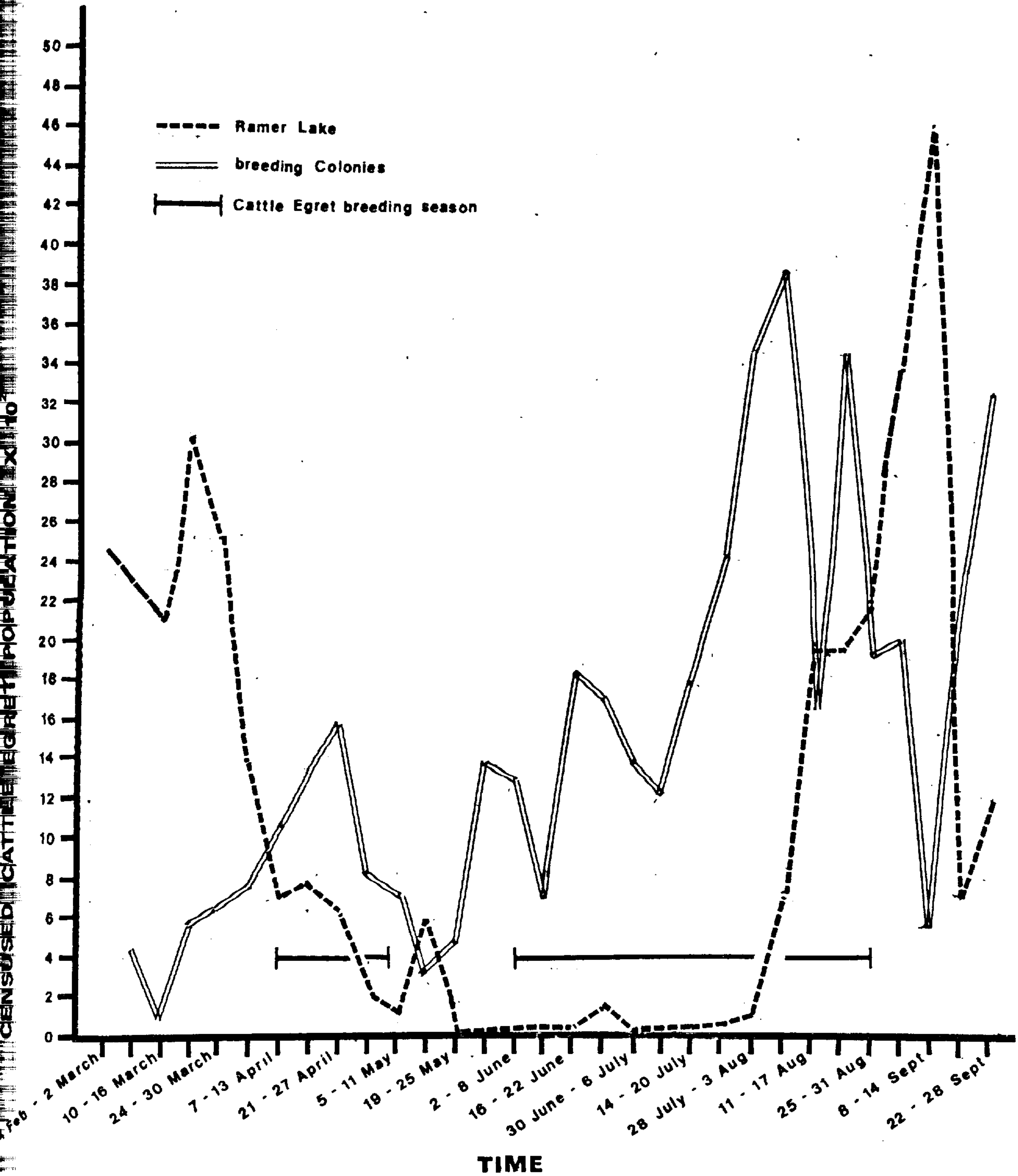

FIG. 3. *Estimated Cattle Egret population from censuses done at Ramer Lake and both the Old and New Colonies during the day and evening.*

were noticed at that roosting area (Fig. 4), and almost never in the evening. It is likely that the Snowy Egrets in the vicinity of the Salton Sea roosted either at the breeding colonies or at some unlocated roost elsewhere.

There were several dips in the estimated populations of both Cattle and Snowy Egrets present at the breeding colonies. However, the two species showed a temporary population decline during the same time interval only twice, the week of 7-13 July and of 11-17 August. The week of 7-13 July was also the dividing interval between two peaks of nest starts for both egret species.

Cattle and Snowy Egret populations that were actively breeding were estimated on two separate days from counts of the total nests present and knowledge of the number of tagged nests. Conservatively, the maximum breeding population of Cattle Egrets was estimated at approximately 1,480 individuals, while that of the Snowy Egrets was estimated at approximately 308 individuals.

Using the same method, separate estimates of the total nests fledged per week for both Cattle and Snowy Egrets were calculated. These were then multiplied by the average number of young fledged per successful nest,

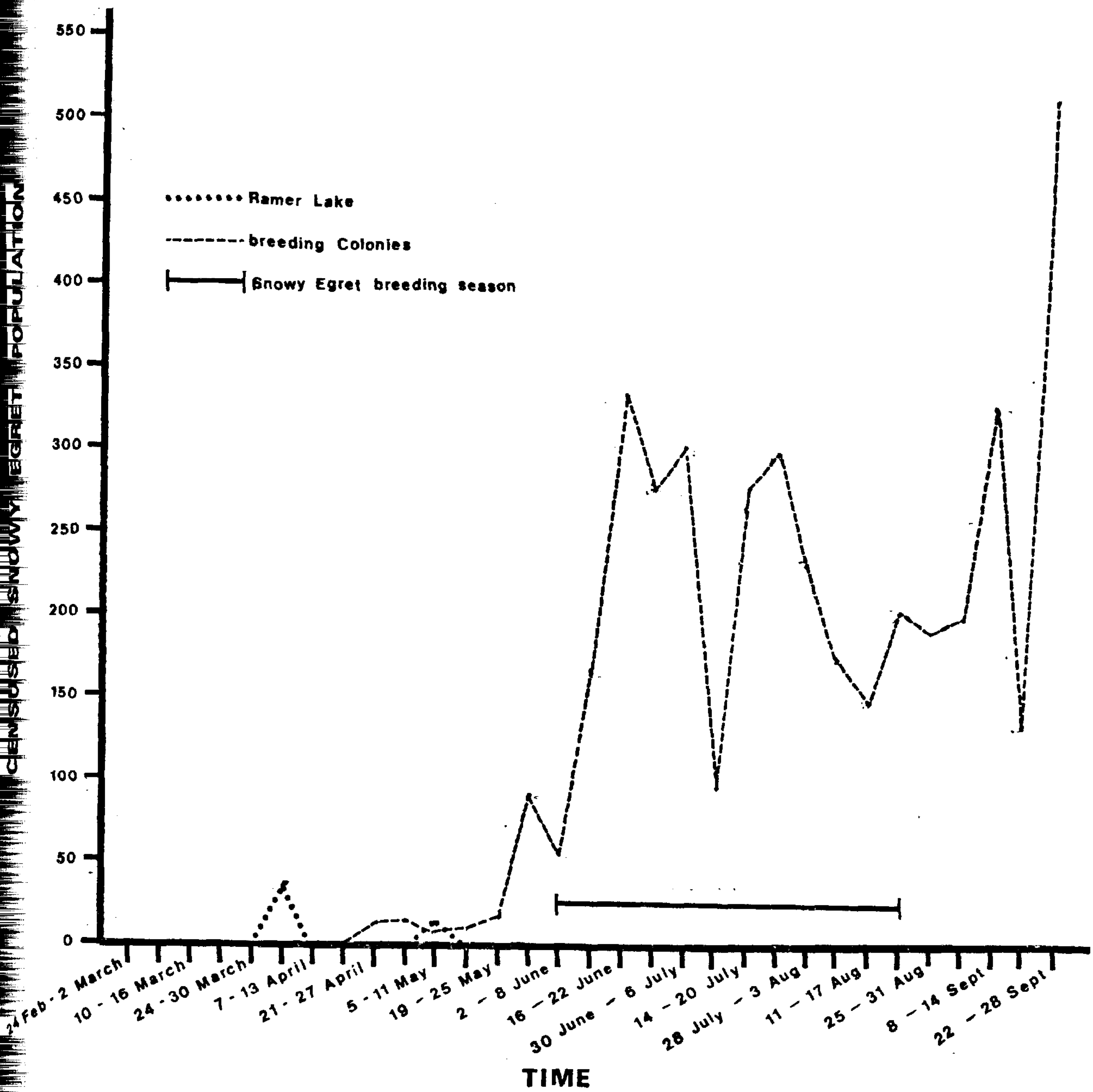

FIG. 4. *Estimated Snowy Egret population from censuses done at Ramer Lake and both the Old and New Colonies during the day and evening.*

1.86 young for Cattle Egrets and 2.90 young for Snowy Egrets. This estimate of total young fledged per species per week was added to the maximum total population-count per species, during the breeding season before any young fledged, to compute the total expected population at the end of the breeding season for both Cattle and Snowy Egrets. This expected total population after breeding was plotted with the actual total population (derived by summing all the evening and within-colony counts) in Figs. 5 and 6.

In Fig. 5, it is quite obvious that the total Cattle Egret population, derived by censusing, from the week of 28 July to 3 August on is substantially larger than the total expected population due to successful breeding alone. From 28 July to 28 September, the maximum and minimum estimates of the total population by censusing is 6,319 and 3,096 Cattle Egrets, and the mean is 4,633 individuals, while the maximum expected population size from breeding is 3,376 Cattle Egrets. Using the maximum and mean total population (from direct censusing) and the maximum expected population due to successful breeding, an estimated excess of from 2,943 to 1,257 Cattle Egrets were seen.

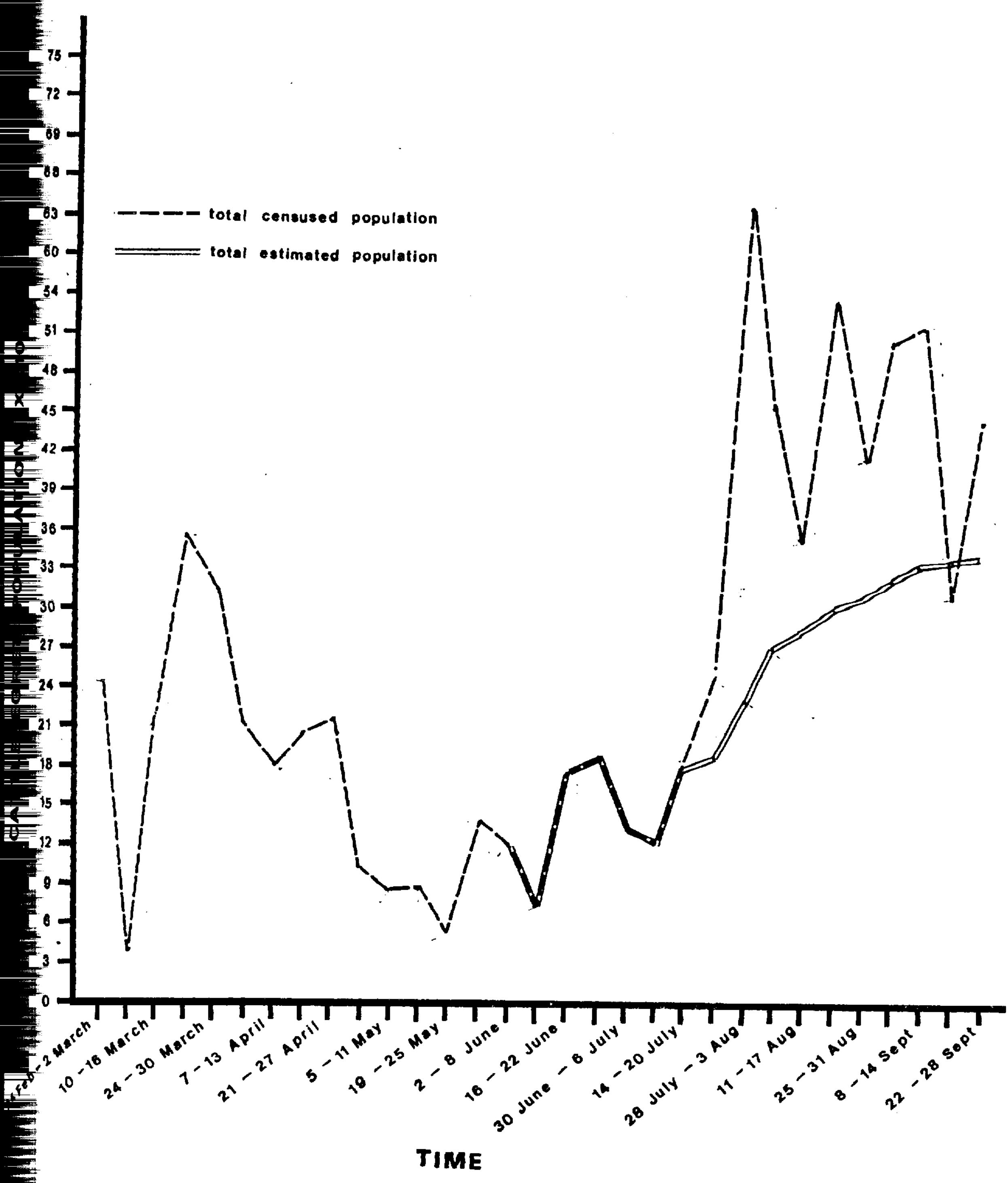

FIG. 5. *Total Cattle Egret population censused at both Old and New Colonies, the north end of Baker Road, the west end of Young Road, and Ramer Lake. Also shown is the estimated maximum breeding population, obtained by adding the total estimated young that fledged to the total counted population.*

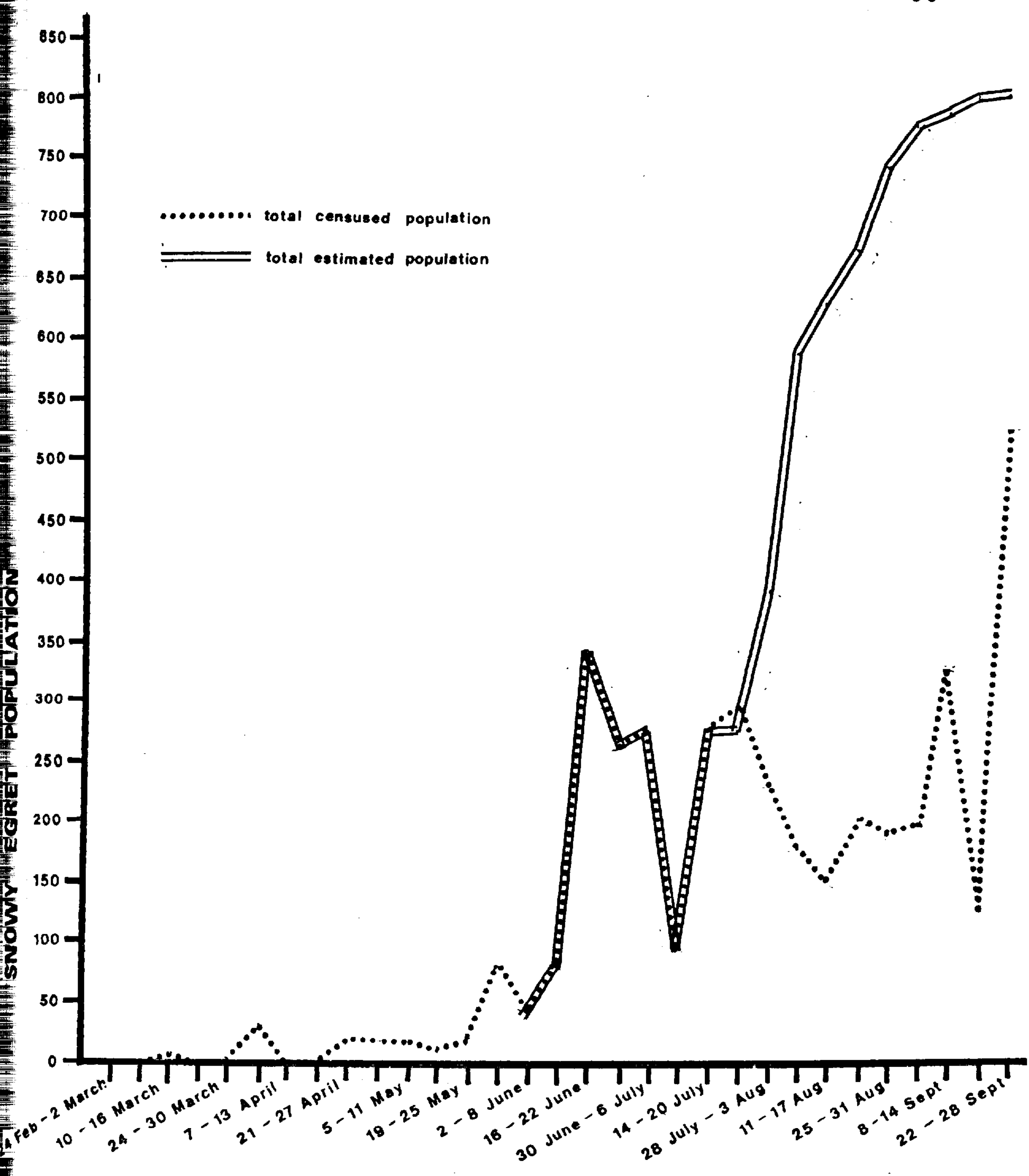

FIG. 6. *Total Snowy Egret population censused at both Old and New Colonies, the north end of Baker Road, the west end of Young Road, and Ramer Lake. Also shown is the estimated maximum breeding population, obtained by adding the total estimated young that fledged to the total counted population.*

The Snowy Egret population trend (Fig. 6) is reversed relative to that of the Cattle Egrets. At the week of 28 July to 3 August, the estimated total population from breeding continues to climb, while the total population derived by censusing drops below the number of egrets present during periods of active nest starts. The average total Snowy Egret population (obtained by censusing) from 28 July to 28 September is 235 egrets, while the maximum expected population due only to successful breeding is 797 egrets, creating a difference of 563 Snowy Egrets that were not seen.

Nest Observations

The date of laying the first egg laid, or the first egg laid that later hatched, was used as a reliable indication of nest starts, which were plotted against weeks during the breeding season (Fig. 7). The percentages of nest starts at different times during the breeding season are shown in Table 1. Designation of the first and second sections of the breeding season is arbitrary, but is based upon the two large, general peaks in nest activity which were present throughout the entire season (Figs. 7 and 8, Tables 2, 3, and 4). These two peaks were created by an extreme reduction of Cattle

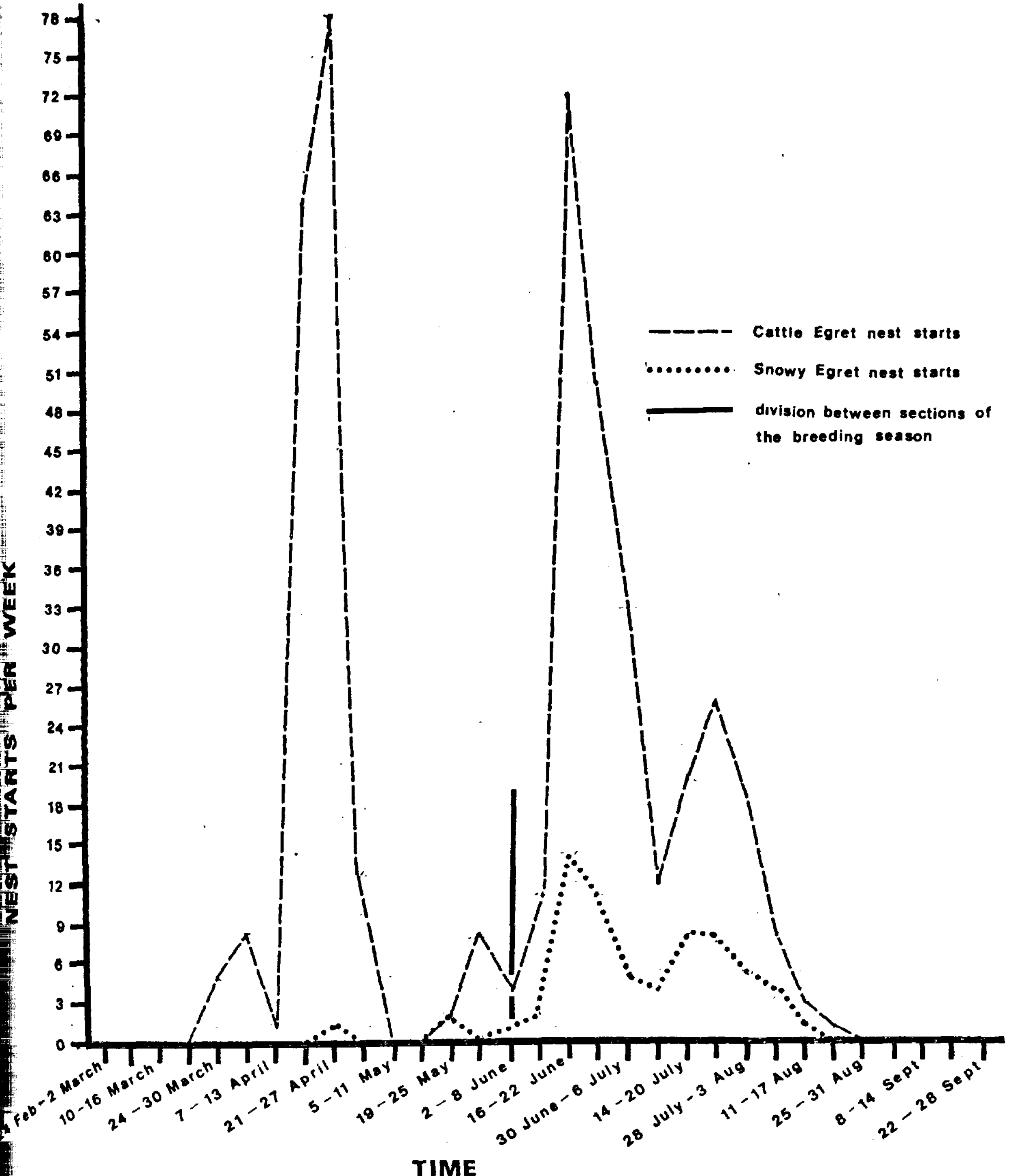

FIG. 7. *The number of Cattle Egret and Snowy Egret nests started per week in the Old Colony. Nests are plotted by the date of the first egg laid.*

TABLE 1. *The percentages by time period of all Cattle and Snowy Egret nests started during the breeding season.*

Section of breeding season	Weeks	Percentage of total Cattle Egret nest starts	Percentage of total Snowy Egret nest starts
First	7 April - 4 May	36.7	1.5
First	5 May - 1 June	2.4	3.0
Second	2 June - 13 July	42.8	50.0
Second	14 July - 31 August	18.1	45.5
Total		100.0	100.0

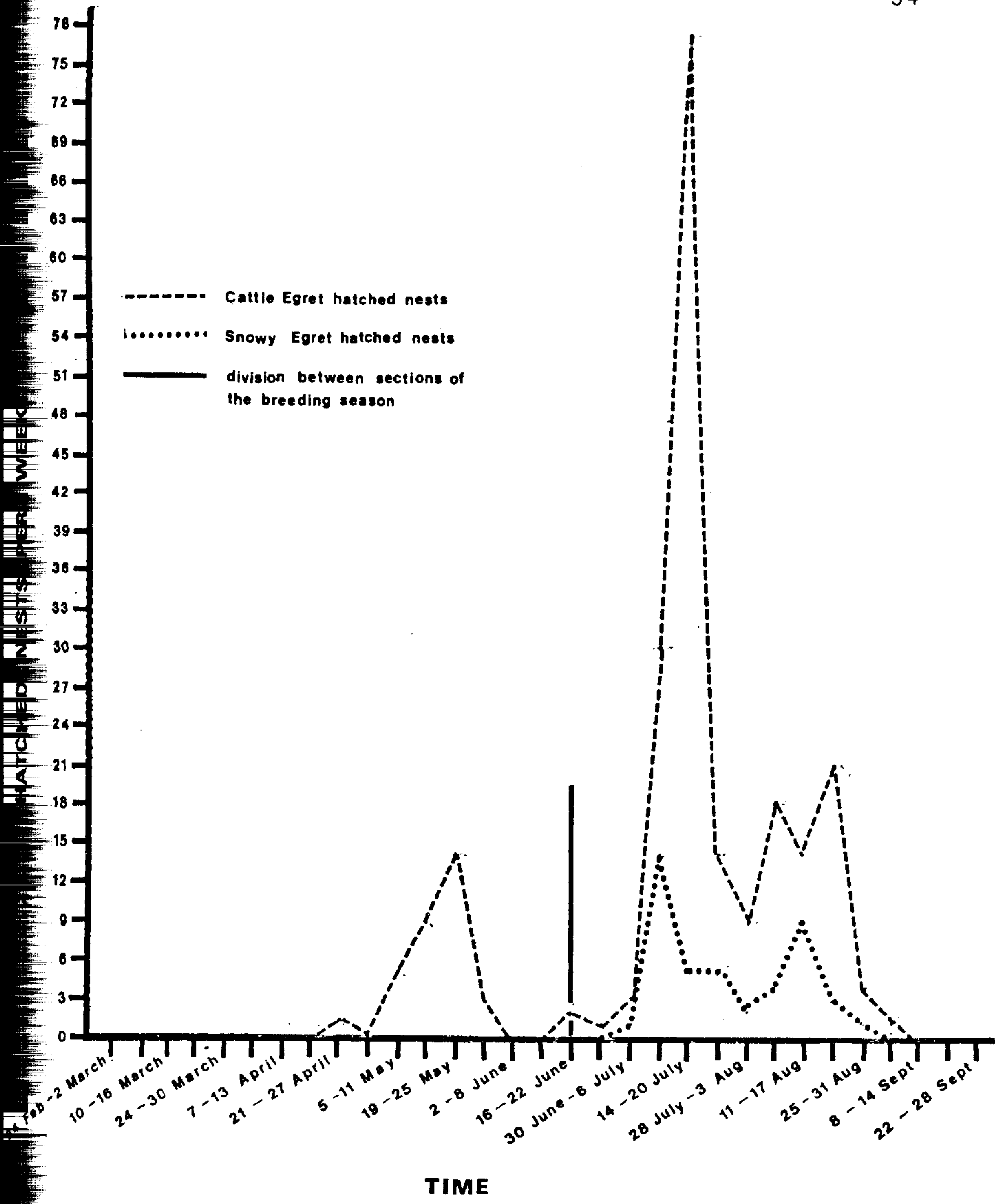

FIG. 8. *Seasonal distribution of all Cattle Egret and Snowy ret nests that hatched eggs. Nests are plotted by the date on ch the first egg hatched.*

TABLE 2. *The number of both Cattle and Snowy Egret nest starts per week which did not hatch eggs in the Old Colony. Nests were tabulated by date of the first egg laid.*

Breeding season	Weeks	Cattle Egret: Total nest starts	Cattle Egret: Nest starts that did not hatch eggs	Snowy Egret: Total nest starts	Snowy Egret: Nest starts that did not hatch eggs
First part	24 March to 30 March	3	2	0	0
	31 March to 6 April	8	8	0	0
	7 April to 13 April	1	0	0	0
	14 April to 20 April	53	44	0	0
	21 April to 27 April	78	57	1	1
	28 April to 4 May	13	13	0	0
	5 May to 11 May	0	0	0	0
	12 May to 18 May	0	0	0	0
	19 May to 25 May	2	2	2	2
	26 May to 1 June	8	4	0	0
Second part	2 June to 8 June	4	3	1	0
	9 June to 15 June	11	1	2	0
	16 June to 22 June	72	6	14	1
	23 June to 29 June	50	11	11	5
	30 June to 6 July	33	20	5	1
	7 July to 13 July	12	1	4	0
	14 July to 20 July	20	5	8	2
	21 July to 27 July	26	10	8	3
	28 July to 3 August	19	4	5	3
	4 August to 10 August	8	5	4	3
	11 August to 17 August	3	2	1	1
	18 August to 24 August	1	1	0	0
	Total	425	199	66	22

TABLE 3. *The total number of both Cattle and Snowy Egret young fledged per week from the Old Colony. Young tabulated by date of hatching.*

Breeding season	Weeks	Total number of young fledged: Cattle Egret	Total number of young fledged: Snowy Egret
First part	2 June to 8 June	1	0
	9 June to 15 June	17	0
	16 June to 22 June	0	0
	23 June to 29 June	0	0
	30 June to 6 July	0	0
Second part	7 July to 13 July	0	0
	14 July to 20 July	6	0
	21 July to 27 July	10	0
	28 July to 3 August	90	25
	4 August to 10 August	91	44
	11 August to 17 August	22	12
	18 August to 24 August	38	7
	25 August to 31 August	20	17
	1 September to 7 September	29	5
	8 September to 14 September	17	3
	15 September to 21 September	5	3
	Total	346	116

TABLE 4. *The seasonal distribution of both Old Colony Cattle Egret and Snowy Egret nests which hatched eggs, but failed to fledge young. Nests were tabulated by date of hatching.*

Breeding season	Weeks	Cattle Egret: Total hatched nests	Cattle Egret: Hatched nests which did not fledge young	Snowy Egret: Total hatched nests	Snowy Egret: Hatched nests which did not fledge young
First part	21 April to 27 April	1	1	0	0
	28 April to 4 May	0	0	0	0
	5 May to 11 May	5	3	0	0
	12 May to 18 May	9	6	0	0
	19 May to 25 May	14	9	0	0
	26 May to 1 June	3	1	0	0
	2 June to 8 June	0	0	0	0
Second part	9 June to 15 June	0	0	0	0
	16 June to 22 June	2	0	0	0
	23 June to 29 June	1	0	0	0
	30 June to 6 July	3	1	1	0
	7 July to 13 July	30	0	14	0
	14 July to 20 July	77	8	5	0
	21 July to 27 July	14	2	5	1
	28 July to 3 August	9	3	2	0
	4 August to 10 August	18	4	4	2
	11 August to 17 August	14	0	9	2
	18 August to 24 August	21	1	3	0
	25 August to 31 August	4	0	1	0
	1 September to 7 September	1	0	0	0
	Total	226	39	44	5

Egret egg-laying from 5 May to 1 June. The Snowy Egrets did not begin to breed in numbers until the second part of the season, 7 weeks after the first Cattle Egrets.

The hatching date of the first egg was used to plot the seasonal distributions of nests containing eggs that hatched for both Cattle and Snowy Egrets (Fig. 8). The percentages of nests with hatched eggs are presented in Table 5 for both species during various time periods. The timing and amount of hatching were similar for both Cattle and Snowy Egrets.

The seasonal distribution of nests with eggs that did not hatch is shown by the date of the first egg laid versus week in the breeding season (Table 2), and Table 6 contains percentages of all of these nests during the breeding season, shown by time period. At $P \leq 0.01$, the shape of the Cattle Egret nest distribution was significantly different from that of the Snowy Egret distribution. The first peak of the breeding season, which failed, accounted for the majority of Cattle Egret nests that did not hatch. Later in the breeding season, Cattle Egrets had a relatively constant proportion of nests showing hatching failures. For Snowy Egrets, the probability of nest failure due to nonhatching increased through the breeding season.

TABLE 5. *The percentage of the total Cattle and Snowy Egret nests that hatched eggs during the breeding season, shown for different time periods.*

Sections of breeding season	Time period	Percentage of total Cattle Egret hatched nests	Percentage of total Snowy Egret hatched nests
First	14 April - 15 June	14.2	0.0
Second	16 June - 3 August	60.1	61.4
Second	4 August - 7 September	25.7	38.6
Total		100.00	100.0

TABLE 6. *The percentage of the total Cattle and Snowy Egret nests that failed to hatch during the breeding season, shown for different time periods.*

Section of breeding season	Time period	Percentage of total Cattle Egret nests that did not hatch	Percentage of total Snowy Egret nests that did not hatch
First	24 March - 11 May	62.3	4.6
First	12 May - 15 June	5.0	9.1
Second	16 June - 13 July	19.1	31.8
Second	14 July - 31 August	13.6	54.6
Total		100.0	100.0

For Cattle Egrets only, the breeding season, in terms of fledging young, consisted of two separate parts, 2 to 22 June (5.3% of all young fledged) and 7 July to 28 September (94.7% of all young fledged) (Tables 3 and 7). These two sections are separated by 3 weeks during which no young were fledged. The Snowy Egrets fledged young only during the second section of the breeding season, 21 July to 28 September, 2 weeks later than the Cattle Egrets. The maximum number of young fledged for both species occurs at the same time, 4 to 10 August. At the beginning of the breeding season, 7 April to 11 May (Table 1), 36.7% of all Cattle Egret nests were started, while only 5.3% of all fledged Cattle Egret nests occurred within the first weeks of fledging, 2 to 22 June (Table 7). Nests started during 7 April to 11 May should have fledged during 2 to 22 June.

The distribution of nests which hatched but failed to fledge is shown in Table 4 by date of hatching versus week within the breeding season. There is very little difference between the two sections of the breeding season in terms of numbers of Cattle Egret nests that failed to fledge young, as 20 nests failed during 14 April to 8 June, and 19 nests failed during 23 June

TABLE 7. *The percentages of the total Cattle and Snowy Egret young that fledged during the breeding season, shown for different time periods.*

Section of breeding season	Time period	Percentage of total Cattle Egret young that fledged	Percentage of total Snowy Egret young that fledged
First	2 June - 6 July	5.3	0.0
Second	7 July - 17 August	62.6	69.8
Second	18 August - 31 August	17.1	20.7
Second	1 September - 28 September	15.0	9.5
Total		100.0	100.0

31 August. All four Snowy Egret nests that failed to fledge young hatched during 23 June to 31 August. When these nests are examined as percentages of all the nests with hatched eggs during the same time period (Table 8), it is obvious that the Cattle Egrets had a large percentage (62.5) of nests that had hatched eggs but failed to fledge young in the first part of the breeding season. Thereafter, the proportion of nests with hatched Cattle Egret eggs that failed to fledge young was relatively constant, but much smaller. All four of the Snowy Egret nests that had hatched eggs, but failed to fledge young, were present in the second part of the breeding season. When examining the nests that did not fledge young as a percentage of all the hatched-egg nests, there is not a significant difference between hatched-egg Cattle Egret nests (17.3%) that failed to fledge young and hatched-egg Snowy Egret nests (9.1%) that likewise failed. However, to be 80% certain of detecting a true difference between these two percentages, a sample size of about 262 nests is needed for each species. The available sample sizes are 226 Cattle Egret nests and 44 Snowy Egret nests, thus the test of these two percentages is inconclusive.

TABLE 8. *The proportion of both Cattle and Snowy Egret nests that hatched eggs but failed to fledge young, at various times during the breeding season, shown as percentages of the total hatched nests for that time period. All nests were tabulated by the date of hatching.*

		Cattle Egret			Snowy Egret		
Sections of breeding season	Time period	Nests hatched during period	Failed nests	Percent hatched nests that failed per time period	Nests hatched during period	Failed nests	Percent hatched nests that failed per time period
First	14 April - 8 June	32	20	62.5	0	0	0
Second	16 June - 3 August	136	14	10.3	27	0	0
Second	4 August - 17 August	32	4	12.5	13	4	30.8
Second	18 August - 7 September	26	1	3.9	4	0	0
Total		226	39		44	4	

The distribution of nest starts was compared to the distribution of nests that fledged young for both species. Nest starts were listed by date of the first egg laid, while fledged nests were listed by date of hatching as there was great variability in the determination of the date of fledging. It was concluded that the shapes of the distributions were significantly different. The results indicate that the events subsequently resulting in nesting failures were not proportionate to the number of nest starts.

Wind effects. Although much the same general pattern is shown, discrepancies between estimates of wind intensity derived from my field notes and from weather station records at Brawley exist (Fig. 9). They were often caused by periods of strong wind on days during which I was not at the Salton Sea. Discrepancies in wind intensity estimates for 31 March to 27 April, 26 May to 1 June, 28 July to 3 August, and 25 to 31 August are of this kind. Recorded wind differences for 23 to 29 June, 14 to 20 July, and 11 to 17 August were probably due to strong wind either late at night, or near midday when I was in the Imperial Valley, but was far away from the Salton Sea area. Some of the

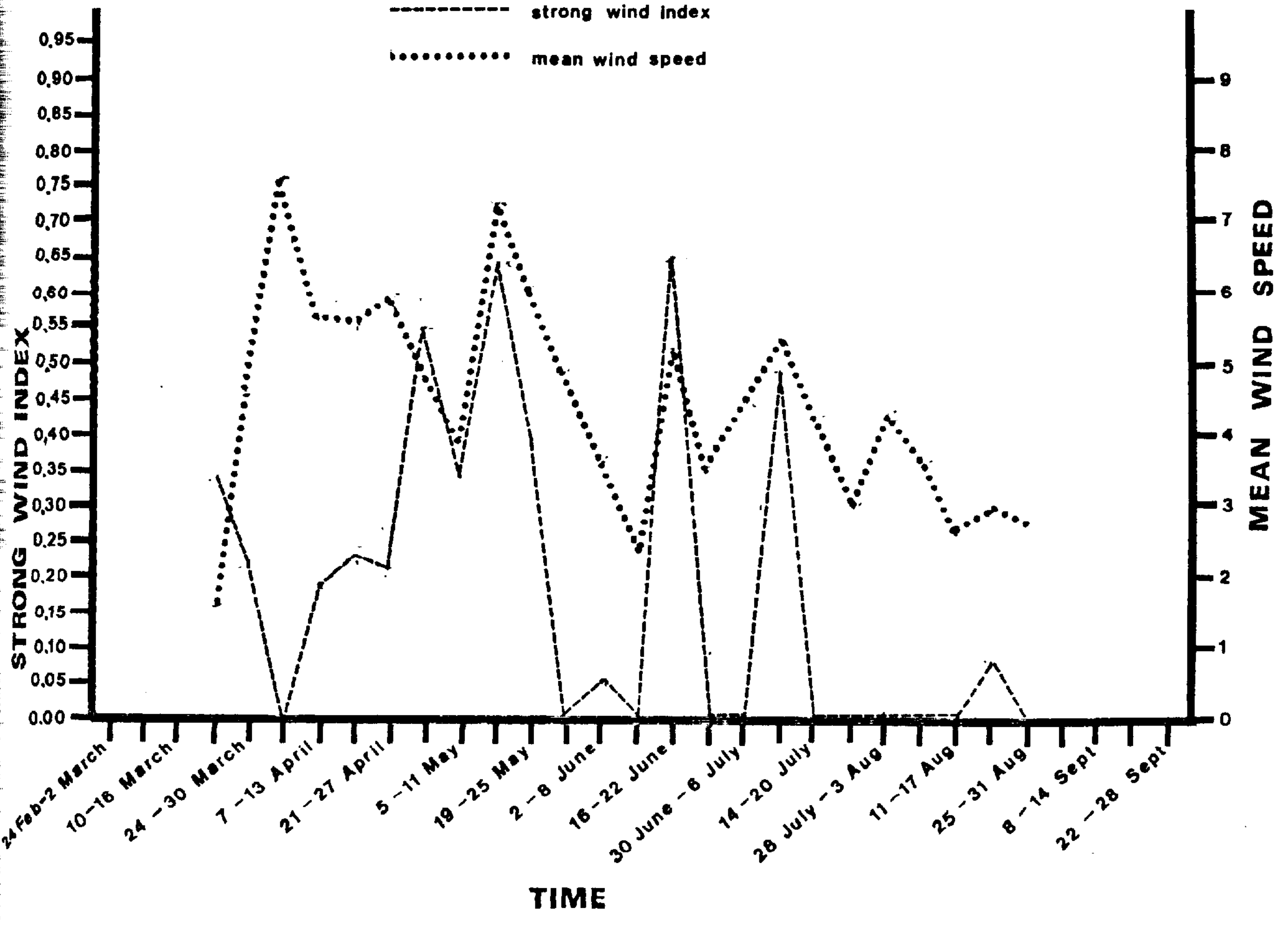

FIG. 9. *The estimated strong wind index and the mean wind speed (km/h) from Brawley are plotted together over the entire breeding season. The strong wind index is a ratio of estimated hours of strong wind divided by estimated hours the investigator was present.*

differences between my records and those at Brawley probably do reflect some differences in wind patterns, however. The Salton Sea, a large body of water lying close to desert areas and mountain ranges, is probably more subject to fluctuation in wind patterns than is Brawley, 31.5 km southeast of the Salton Sea and surrounded by agricultural land.

Both egret species apparently suffered damage to their reproductive effort through lengthy periods of sustained strong wind. In the first part of the breeding season, the number of Cattle Egret nest starts was sharply reduced from a high of 78 during 21 to 27 April (Fig. 7) to a low of 0 during 5 to 18 May. An additional 2 nest starts from 19 to 25 May, and 8 from 26 May to 1 June were observed. This reduction in nest starts coincides with 5 weeks of fairly continuous strong wind during 28 April to 1 June (Fig. 9). From 31 March to 6 April high winds also occurred; the 8 recorded nest starts during this period occurred after these winds had abated. During the first portion of the breeding season, when winds were a severe factor, 92.8% of all Cattle Egret nests that were started failed to fledge young. All 3 Snowy Egret nests started likewise failed.

In the latter portion of the breeding season, two periods of strong wind occurred between 16 and 22 June and 7 and 13 July (Fig. 9). There were fewer continuous days of strong wind between 16 and 22 June, than between 7 and 13 July. A sharp dip in the number of both Cattle and Snowy Egret nest starts occurred from 7 to 13 July. Between 16 and 22 June, however, the largest number of nest starts, 72 Cattle Egret and 14 Snowy Egret nest starts, of the entire breeding season was recorded. Most of these, 59.3%, were begun on two days after strong winds had abated. During the second part of the breeding season, when winds were generally less intense, only 7.3% of all Cattle Egret and 6.3% of all Snowy Egret nests that were started failed to fledge young.

Reproductive Success

Snowy Egrets laid significantly larger clutches than did the Cattle Egrets (Table 9). There was no difference in clutch size between the Old and New Colonies for either Cattle or Snowy Egrets. For both species, nests with hatched eggs had the largest clutches; which is very likely due to the fact that nests with eggs that did not hatch included nests

TABLE 9. *Average clutch size in the Salton Sea breeding colonies during 1974.*

Colony	Nest category	Cattle Egret			Snowy Egret			Significance level of difference between means
		N (nests)	$\overline{X}$	SD	N (nests)	$\overline{X}$	SD	
New	All nests studied	145	2.47	1.08	40	3.60	1.32	$P \leq 0.05$
Old	All nests studied	425	2.58	1.01	66	3.96	1.18	$P \leq 0.05$
Old	Nests with eggs that hatched	226	2.88	0.91	44	4.43	0.66	$P \leq 0.01$
Old	Nests with eggs that did not hatch	199	2.24	1.02	22	3.00	1.41	$P \leq 0.01$

which had been abandoned before the clutch had been completed. Since Snowy Egrets laid significantly more eggs per nest than did Cattle Egrets, reproductive success is shown as the mean of percents for individual nesting successes.

Data from the second portion of the breeding season (31 May to 10 July) were examined for possible relationships between date and clutch size. This period was chosen because so many Cattle Egret nests failed in the first portion of the breeding season that clutch size may have been influenced by abnormal reproductive activity. In addition, Snowy Egrets bred almost exclusively during the second portion of the season. The mean size of both Cattle and Snowy Egret clutches early in this part of the breeding season was significantly ($P \leq 0.01$) larger than their mean clutch size later in this part of the breeding season.

Snowy Egrets had significantly higher percentages of damaged eggs in all nest categories than did Cattle Egrets (Table 10). In 425 Cattle Egret nests, 23.5% had at least one damaged egg; but in 66 Snowy Egret nests, 54.6% contained at least one damaged egg. Both species show a tendency toward a higher percentage of damaged eggs in nests that failed to hatch than in

TABLE 10. *The mean percent of the total eggs laid per nest that had eggshell damage, shown for both Cattle and Snowy Egrets in the Old Colony at the Salton Sea.*

Category	Cattle Egret			Snowy Egret			Significance level of difference between means
	N (nests)	$\overline{X}$	SD	N (nests)	$\overline{X}$	SD	
All nests studied	425	9.86	20.24	66	19.07	19.55	$P \leq 0.01$
Nests with hatched eggs	226	8.80	17.61	44	18.30	18.08	$P \leq 0.01$
Nests with eggs that failed to hatch	199	11.10	22.90	22	20.60	25.90	$P \leq 0.10$

those that did hatch. This trend is not statistically significant, however.

Detailed information on hatched eggs and fledged young is presented in Table 11. For both species, about the same proportion of eggs hatched in nests in which at least one egg hatched: 64.8% of 716 eggs for Cattle Egrets and 69.1% of 217 eggs for Snowy Egrets. The initially larger Snowy Egret clutch is reflected in the mean number of eggs hatched and young fledged, which is significantly greater than those for the Cattle Egret. When these data are compared as mean percentages of the total eggs laid per nest, it is obvious that both egrets had about the same percentage success in hatching and fledging.

In the Old Colony, Cattle Egrets lost a significantly higher proportion of all eggs laid during the breeding season, 64.6% of 1,013 eggs, than did Snowy Egrets, which lost 45.9% of 292 eggs. The greater Cattle Egret loss reflects the extensive nest failures in the first part of the breeding season. Table 12 shows data on eggs and young lost from nests with hatched eggs and fledged young. Nests in which eggs hatched lost about the same proportion of eggs and young for both species. Both species also lost about the same

TABLE 11. *Hatched eggs and fledged young from the Old Colony, presented as means per nest that fledged young, and as mean percentages of the total eggs laid per nest that fledged young.*

Category	Cattle Egret			Snowy Egret			Significance level of difference between means (NS = not significant)
	N (nests studied)	$\overline{X}$	SD	N (nests studied)	$\overline{X}$	SD	
Hatched eggs per nest with hatched eggs	226	1.93	0.83	44	3.11	1.30	$P \leq 0.01$
Hatched eggs per nest that failed to fledge young	39	1.39	0.71	4	3.25	1.71	$P \leq 0.05$
Hatched eggs per nest that later fledged young	187	2.04	0.81	40	3.10	1.28	$P \leq 0.01$
Fledged young per nest that had fledged young	187	1.86	0.74	40	2.90	1.22	$P \leq 0.01$
Percentage of hatched eggs per nest that later fledged young	187	69.20	26.80	40	66.00	25.40	NS
Percentage of fledged young per nest that had fledged young	187	63.80	27.00	40	61.50	24.00	NS

TABLE 12. *Data on eggs and young lost from Cattle and Snowy Egret nests with hatched eggs and fledged young in the Old Colony.*

Category	Cattle Egret			Snowy Egret			Significance level of difference between means (NS = not significant)
	N (nests studied)	$\overline{X}$	SD	N (nests studied)	$\overline{X}$	SD	
Percentage of total eggs laid per nest that were lost from nests with hatched eggs	226	22.90	26.10	44	23.50	24.30	NS
Young lost from nests with hatched eggs	226	0.39	0.67	44	0.48	1.07	NS
Lost young as a percentage of the total eggs laid per nest with fledged young	187	5.50	12.80	40	4.40	9.30	NS

proportion of young, expressed as a mean percentage of the total eggs laid per nest in which young fledged. Table 13 gives percent mortality of eggs and young for nests in which eggs hatched. Both species show about the same egg mortality, but Cattle Egrets possess a slightly higher nestling mortality, which gives them a higher overall percent mortality. This fact is probably another result of the larger Snowy Egret clutch size. Both species lost about the same proportion of young per nest, but since Snowy Egrets had more young from which to lose, they had a lower percent nestling and overall mortality.

In both Cattle Egret and Snowy Egret nests with two or more young, nestling mortality increased with brood size (Tables 14 and 15). Cattle Egret broods of one showed higher mortality rates than broods of four, while Snowy Egret broods of one had mortality rates equal to those of broods of four. Snowy Egrets also appeared to have lower mortality rates than Cattle Egrets for corresponding brood sizes. For both species, the decrease in brood size caused by nestling mortality from hatching to fledging was small, and not statistically significant.

TABLE 13. *Percent mortality of Cattle and Snowy Egret eggs and young in nests with hatched eggs at the Old Colony.*

Categories of mortality	Percent mortality Cattle Egret	Percent mortality Snowy Egret
Laying through hatching	31.7	30.9
Hatching to fledging	29.4	22.7
Overall mortality from laying to fledging	51.8	46.6

TABLE 14. *Cattle Egret nestling mortality and productivity in relation to brood size at the Salton Sea.*

Brood size	1	2	3	4
Number of broods	79	90	50	7
Percent nestling mortality	35.4	11.7	20.7	28.8
Average number of young produced per nest	0.65	1.77	2.38	2.86

TABLE 15. *Snowy Egret nestling mortality and productivity in relation to brood size at the Salton Sea.*

Brood size	1	2	3	4	5
Number of broods	6	8	13	9	8
Percent nestling mortality	16.7	6.3	12.8	16.7	20.0
Average number of young produced per nest	0.83	1.88	2.62	3.33	4.00

Nesting success is the percentage of all eggs laid that produce fledged young, and breeding success is the number of fledged young produced per breeding adult (Siegfried 1972b). Cattle Egrets fledged young from 25% of the total eggs laid, and Snowy Egrets fledged young from 31%. The lower Cattle Egret nesting success is probably a result of the large scale nesting failures early in the breeding season. Cattle Egrets produced 0.41 fledged young per breeding adult, while Snowy Egrets produced 0.88 young per breeding adult. The lower Cattle Egret breeding success again reflects their smaller clutch size. They laid fewer eggs per adult, lost the same proportion of eggs and young per nest, and fledged fewer young per breeding adult than did Snowy Egrets.

Mixed Species Nests

In the Old Colony at the Salton Sea, 9 mixed Cattle Egret-Snowy Egret nests were found. In 8 of the 9 nests, most of the eggs were Snowy Egret eggs; in 6 of these a single Cattle Egret egg appeared during the incubation period. In 4 of these 6 nests, the Cattle Egret egg vanished or failed to hatch. In the other 2 nests, the single Cattle Egret egg hatched; one of these resulted in a fledged Cattle Egret. In the other nest, the young Cattle Egret chick was found crushed and dead. Later a fresh Snowy Egret egg was laid in this nest; this egg subsequently vanished. Two of the 8 nests with mostly Snowy Egret eggs later acquired 2 Cattle Egret eggs. One of these nests fledged 2 Cattle Egret young; a fresh Cattle Egret egg was also laid near the end of the nesting period. In the other nest, one Snowy Egret chick fledged and another was found dead. The 2 Cattle Egret eggs never hatched. In the one nest that began with only Cattle Egret eggs, 1 Snowy Egret egg was added. Later the entire nest vanished.

The species tending these mixed-egg nests was positively identified in only one of the nine cases. This parent was a Snowy Egret, and the nest involved fledged one Snowy and one Cattle Egret. It is suggestive that in the mixed species nest that fledged two Cattle Egret chicks, the freshly regurgitated food pellets were almost always entirely fish. Snowy Egrets feed almost exclusively on fish at the Salton Sea, and although occasional fish have been noted in nestling Cattle Egret food boluses (Foster and Tiller 1973), they never form a major part of the diet.

Even in an active, mixed species heronry, nests containing eggs of more than one species are rare. However, such nests constituted 1.8% of the nests at the Salton Sea. The number of nesting attempts at particular tagged nest sites ranged from one to four. Successive attempts were not necessarily by birds of the same species. Mixed-egg nests could have resulted from accidents relating to the changing occupants of particular nests, or simply have been deposition of eggs by females whose nests had been lost and who subsequently produced an egg that had to be laid somewhere. In summary, Cattle Egrets added one or, rarely, two eggs to an already existing Snowy Egret nest in eight cases; in only one case was a Snowy Egret egg added to an already established Cattle Egret nest. However, this ratio is not too unexpected, since Cattle Egrets were usually at least five times more abundant than Snowy Egrets in the colonies. Shanholtzer et al. (1970) noted two mixed-species nests at McKinney's Pond Rookery, Georgia; a Cattle Egret nest with two Cattle Egret eggs and one White Ibis egg, and a White Ibis nest with three Ibis eggs and one Cattle Egret egg. Unfortunately, these nests were not followed during the breeding season. Mackworth-Praed and Grant (1957) note that in Africa

Cattle Egrets often nest in association with other herons and egrets, and that it is by no means unknown for an egg to be deposited and hatched in the nest of another species.

Cattle Egret Nestling Diet

The composition of 50 food boluses regurgitated by nestling Cattle Egrets is summarized in Table 16. Although the food items were sorted and identified, their volumes were not measured. An average volume per item in each food category was derived from data on numbers, volume, and percent total volume of similar items in Cattle Egret diets reported by Jenni (1973) and Fogarty and Hetrick (1973). In terms of total volume, 53.0% of the Cattle Egret diet consisted of insects (crickets, grasshoppers, earwigs, caterpillars, and flies); 18.5% consisted of spiders; 21.5% consisted of mice; and a combined total of 16.0% consisted of crawfish, earthworms, fish, and lizards.

Shell Thickness and Pesticide Residues

Measurements of eggshell thickness show significant shell thinning for both species (Table 17). All categories of Snowy Egret and Cattle Egret eggs from the

TABLE 16. *Contents of 50 boluses regurgitated by nestling Cattle Egre at the Salton Sea, southern California.*

Food category	Total number of items	Percent of total number of items	Derived average volume (ml) per item*	Volume (ml per food category
INVERTEBRATES				
Insecta				
Orthoptera	483	35.0	0.09	43.47
Dermaptera	169	12.3	0.15	25.35
Homoptera	1	0.1	0.09	0.09
Coleoptera	3	0.2	0.04	0.12
Lepidoptera (total)	97	7.0		
Larvae	84	6.1	0.30	25.20
Adults	13	0.9	0.12	1.56
Diptera	172	12.5	0.18	30.96
Arachnida	317	23.0	0.14	44.38
Crustacea				
Decapoda	1	0.1	2.65	2.65
Annelida				
Oligochaeta	22	1.6	0.30	6.60
VERTEBRATES				
Fish	4	0.3	2.65	10.60
Reptilia	7	0.5	2.65	18.55
Mammalia				
Rodentia	6	0.4	5.00	30.00
Grand total	1379	100.0%		239.53

*Average volume per item in a food category was calculated from data gi (1973) and Fogarty and Hetrick (1973).

†Means the value was less than 0.1%.

TABLE 17. *Eggshell thickness and percent thinning for Snowy Egrets and Cattle Egrets at the Salton Sea.*

Species	Egg category	Number of eggs	Mean (mm)	±95% confidence limit	Percent eggshell thinning
Snowy Egret	Pre-1953 museum eggs	179	0.229	±0.003	
	Hatched, broken, & analyzed for pesticides**	49	0.191	±0.006	16.6
	Analyzed for pesticides only**	30	0.195	±0.006	14.9
	Hatched & broken only	19	0.186	±0.011	18.8
	Broken only	14	0.179	±0.013	21.8
	Hatched only	5	0.204	±0.017	10.9
Cattle Egret	Pre-1953 museum eggs	20	0.237	±0.009	
	Hatched, broken, & analyzed for pesticides	*	*	*	*
	Analyzed for pesticides only	*	*	*	*
	Hatched & broken only	22	0.196	±0.011	17.3
	Broken only	17	0.196	±0.013	17.3
	Hatched only	5	0.194	±0.021	18.1

*The collected Cattle Egret eggs have not yet been analyzed for pesticide residues.

**Shells from eggs analyzed for pesticides still contained moisture, and therefore bias the percentage thinning downward. These figures were not used for comparison.

Salton Sea were significantly thinner than the pre-1953 museum eggs. Data from both hatched and broken eggs show thinning of 18.8% for Snowy Egrets and 17.3% for Cattle Egrets. For Snowy Egrets, this difference is even more striking when only broken eggs are considered, equalling 21.8%. The Snowy Egret eggshells from the pesticide analysis are not included in this comparison because, unfortunately, these shells had not dried completely and comparable measurements of dry shells could not be obtained.

Appreciable quantities of DDE and lower levels of DDT, DDD, dieldrin, and PCB were found in Snowy Egret eggs (Table 18). Cattle Egret eggs were also collected, but have not yet been analyzed. Only DDE, both as ppm wet weight and ppm in yolk, was significantly correlated with decrease in eggshell thickness ($r = -0.43$, $P \leq 0.01$). Dieldrin and PCB were not significantly correlated with eggshell thickness. DDE residue levels were very slightly ($r = 0.45$, $P \leq 0.20$) correlated with the percent damaged eggs per nest, and were not correlated with the total eggs laid per nest.

Pesticide residues found in the two juvenile Cattle Egrets are reported as ppm wet weight. Their brains contained 0.02 and 0.12 ppm DDE, and 0.04 and

TABLE 18. *Pesticide residues presented in ppm wet weight and ppm in yolk for Snowy Egret eggs from the Salton Sea.*

Concentration	Pesticides	N	$\overline{X}$	±95% confidence limit	Range (ND = not detectable)
	DDE	28	1.7	±0.27	0.8 - 4.2
	DDT	28	0.2	±0.14	ND - 1.7
ppm wet weight	DDD	28	0.1	±0.10	ND - 1.3
	dieldrin	28	0.18	±0.06	ND - 0.67
	PCB	28	0.8	±0.53	ND - 6.9
	DDE	28	8.0	±1.3	4.1 - 20.3
	DDT	28	0.8	±0.7	ND - 8.3
ppm in yolk	DDD	28	0.5	±0.4	ND - 6.1
	dieldrin	28	0.86	±0.31	0.08 - 3.40
	PCB	28	4.0	±2.6	ND - 33.3

0.04 ppm dieldrin; while their livers held 0.41 and 0.21 ppm DDE, and 0.07 and 0.03 ppm dieldrin.

Banding and Tagging

During the 1974 breeding season at the Salton Sea, 132 juvenile and 5 adult Cattle Egrets were banded, wing tagged, and marked with picric acid dye. An additional 136 juvenile Cattle Egrets were leg banded and marked with dye, and 66 juvenile Snowy Egrets were leg banded.

DISCUSSION

Population Estimates

Although Cattle Egrets were first recorded in 1969 as breeding in the New River delta at the Salton Sea, no estimates of breeding populations in 1969 or 1970 are available. In May 1971, 50 active Cattle Egret nests and 100 Snowy Egret nests were seen; in May 1972, 100 active nests each of Cattle and Snowy Egrets were observed; and in May 1973, 630 active Cattle Egret nests and 70 active Snowy Egret nests were reported (Jim Crew and Don V. Tiller, personal communication). In 1974, I conservatively estimated that there were 740 active Cattle Egret nests and 154 Snowy Egret nests. Thus, the breeding Cattle Egret population is continuing to increase at the Salton Sea. However, conclusions about the Snowy Egret breeding population are less easily drawn. Prior to 1974, all estimates are from single observations made in May. The 1974 study documented a very late start to the Snowy Egret breeding season; therefore it is quite possible that additional, uncounted nests existed later in the 1971, 1972, and 1973 breeding seasons. The 70 Snowy Egret nests seen in May 1973 appeared to be limited to the outer fringes of a teeming Cattle Egret colony, whereas nest-site segregation did not appear to exist at any time during the entire 1974 breeding season. If it is assumed that an expanding Cattle Egret population was negatively affecting the Snowy Egret population by utilizing the vast majority of nest sites, then the wind-affected Cattle Egret nesting failure in the first part of the 1974 breeding season may have given the Snowy Egret breeding population the opportunity to claim more and better nesting sites than in the previous year. This opportunity would have been present while the breeding Cattle Egrets were undergoing the physiological changes required to initiate renesting activity. However, there appeared to be no lack of suitable nesting sites to the immediate southeast and northwest of both colonies, even during the most active portions of the breeding season. Thus, there is no strong evidence that Cattle Egrets compete with Snowy Egrets for nest sites.

The large fluctuations in the population estimates (Figs. 2, 3, 4, 5, and 6) are probably due to a combination of factors. It is possible that many egrets occasionally returned to the colonies or roosts before my counts were begun. It was also difficult to estimate numbers in large, dense flocks when they arrived swiftly and when the flocks were closely packed together. When there was a strong wind blowing (28 April to 25 May, 16 to 22 June, and 7 to 13 July) all egrets tended to fly low, and many would fly down the New River where their numbers were almost impossible to estimate because of the brush. However, this effect was consciously minimized by obtaining estimates on extra evenings following periods of high wind.

Estimates of Cattle and Snowy Egrets capable of flying, obtained by direct censusing, differed strikingly from those expected on the basis of successful breeding alone (Figs. 5 and 6). Since an unexpected excess of 1,257 to 2,943 Cattle Egrets were seen during the same weeks that an expected 563 Snowy Egrets were not seen, it is possible that the missing Snowy Egrets were counted as Cattle Egrets during the evening flights into the breeding colonies. However, this explanation fails to account for 694 to 2,380 extra Cattle Egrets.

The two species could not be distinguished at a distance when flying, but it is unlikely that many Snowy Egrets were misidentified as Cattle Egrets, since Cattle Egret flocks could be seen approaching from quite a distance and since they arrived from different directions than did birds positively identified as Snowy

Egrets. Snowy Egrets began to fly into the colonies from 0.5 to 1.5 h later than the Cattle Egrets, and some individuals were always observed feeding in the marsh at the north end of Baker Road during the evening. During the day, Snowy Egrets were also observed feeding within both colonies, especially in the shallower water of the New Colony. Fig. 4 shows that although Snowy Egrets occasionally roosted at Ramer Lake, this occurrence was rare and the majority of Snowy Egrets occurred near the New River delta. Therefore, it is possible either that many Snowy Egrets were feeding within the New River delta in the evening and returned to the colonies at night without being seen, or that they had night roosts at other unknown locations. These interpretations suggest that Snowy Egrets are more isolated ecologically from Cattle Egrets, in terms of diurnal activity pattern and possible roosting sites, than had been previously suspected.

In the eastern United States, spring and fall movements of Cattle Egrets through the Dry Tortugas have been observed by Browder (1973) and Harrington and Dinsmore (1975). On the Pacific Coast, the Cattle Egret was observed in the vicinity of San Diego before it appeared in northwestern Baja California in 1967; it was also seen along the west coast of Mexico in 1965, and was becoming rather common there by 1967 (Hubbs 1968). Zimmerman (1973) recorded the species in December of 1971 and 1972 in northern inland Mexico, and since some of those birds were seen in desert areas, he suggested the possibility of transcontinental movement. The Salton Sea is located in the northern end of the Imperial Valley, which is geomorphologically a northward extension of the Gulf of California. Many spring and fall migrant shorebirds which move up and down the west coast of Mexico and the Gulf of California stop over at the Salton Sea, and several sea birds, although uncommon to casual in occurrence, have been recorded at the Salton Sea between July and October (McCaskie 1970). The estimated 1,257 to 2,943 extra Cattle Egrets recorded from 28 July to 28 September may therefore have been individuals migrating or dispersing from a colony located in the Colorado delta area or along the west coast of Mexico, where breeding may have been completed earlier than at the Salton Sea.

Reproductive Effort

Lack (1968) views the breeding strategies of birds as being adjusted by natural selection to maximize the number of surviving young. Thus, in nidicolous birds, the clutch size should be that which produces a brood size from which the most young fledge, the critical factor being the rate at which parents can supply food to the brood. Much of the information on determination of clutch size in birds has been reviewed by Klomp (1970). The proximate determination of clutch size involves the modification of mechanisms controlling follicle growth and ovulation by internal and external factors. Clutch size may be influenced by age of the female, date of laying, population density, habitat and weather conditions, food availability, and perhaps by still other conditions serving as predictors of food availability when the young have hatched. Ultimate factors are those which have guided the evolution of clutch size and its proximate determinants. Some of the potentially important ultimate factors are: food availability for the young, predation pressure, and temperature regulation by nestlings. The last factor would be important in very large broods or hot environments, when heat loss must be maximized.

The breeding adaptations of birds are complex and interrelated. However, Klomp (1970) concludes that information on well-studied species supports Lack's hypothesis, and points out several of its implications. For example, starvation of the young should occur not only in abnormally large broods, but also in broods of normal size when the food supply is below average. Nestlings in broods larger than normal should on the average be undernourished, therefore nestling weight should decrease with an increase in brood size. As a result, differential mortality will cause broods larger than the commonest one to produce fewer, not more, surviving young. This differential mortality can extend into the post-fledging period. Data obtained from the Salton Sea tend to support these conclusions.

Cattle Egrets had an average clutch of 2.58 eggs at the Salton Sea. Siegfried (1972b) observed a mean clutch of 2.59 eggs at Paarl, South Africa. Bowen et al. (1962) report a mean clutch of 2.6 from Ghana; Jenni (1969) shows a mean clutch of 3.5 at Lake Alice, Florida; and Weber (1975) reports an average clutch of 2.86 at Lake Griffin, Florida. Clutch size was found to decrease significantly in later portions of the breeding season at the Salton Sea and in South Africa (Siegfried 1972b), but no significant difference between early and late clutches could be established at Lake Alice, Florida (Jenni 1969). This relationship was not examined in the other studies. There is no significant difference in the clutch size noted at the Salton Sea for Cattle Egrets and those reported from South Africa and Ghana. Salton Sea clutches average much smaller than those at Lake Alice or Lake Griffin, Florida. Lack's (1968) theory of clutch size determination suggests that this large difference, especially for 1960, may reflect greater food availability for Cattle Egrets in Florida than at the Salton Sea and other areas. Possible pesticide effects will be discussed later.

Mortality figures for various populations are presented in Table 19. At the Salton Sea, Cattle Egrets fledged 0.41 young per breeding adult from 25% of the total eggs laid; 0.43 young per breeding adult were fledged from 34% of all eggs laid at South Africa (Siegfried 1972b), and 0.50 young per breeding adult were fledged from 62.5% of the total eggs laid at Lake Griffin, Florida (Weber 1975). Comparable values for nesting and breeding success were not given and could not be calculated for Ghana or for Lake Alice, Florida.

Some retarded growth due to starvation of the youngest and smallest Cattle Egret chicks, usually in

TABLE 19. *Percent Cattle Egret breeding mortality at the Salton Sea and other locations.*

Year	Location	Egg mortality, from laying through hatching	Nestling mortality, from hatching to fledging	Overall mortality
1974	Salton Sea, Ca.	31.7	29.4	51.8
1965-1967[a]	Paarl, South Africa	21.2	26.4	46.6
1960[b]	Ghana, Africa	38.0	54.0	72.0
1960[c]	Lake Alice, Florida	10.6	8.2	17.9
1971[d]	Lake Griffin, Florida	12.5	28.6	37.5

[a]Siegfried (1972b).

[b]Bowen et al. (1962).

[c]Jenni (1969).

[d]Weber (1975).

broods of three or more, was observed at the Salton Sea, in Africa (Siegfried 1972b), and in Florida (Jenni 1969, Weber 1975). However, Cattle Egret brood size at the Salton Sea showed only a slight decrease from hatching to fledging. Jenni (1969) observed a decrease in the number of Cattle Egret chicks in larger broods, but the decrease in young per brood from hatching to fledging was slight. The Lake Alice Cattle Egrets in 1960 had the lowest figures for egg, nestling, and overall mortality. They also exhibited no effect of season on clutch size, unlike the Cattle Egrets of South Africa, and the Salton Sea, suggesting from Lack's hypothesis that food remained readily available throughout the breeding season.

Snowy Egrets had a mean clutch of 3.96 eggs at the Salton Sea in 1974, an average clutch of 3.9 at Lake Alice, Florida, in 1960 (Jenni 1969), and a mean clutch of 3.24 at Sapelo Island, Georgia, in 1955 (Teal 1965). Snowy Egrets were also recorded as breeding at Lake Griffin, Florida (Weber 1975), at Alligator Bay, North Carolina (Grant 1971), and elswhere, but quantitative data on breeding biology are not available. A significant seasonal decrease in clutch size occurred at both the Salton Sea and Lake Alice. Snowy Egret egg and nestling mortality (Table 20) is similar to that of Cattle Egrets (Table 19). At the Salton Sea, Snowy Egrets fledged from 31% of all eggs laid and 0.88 young were fledged per breeding adult. Young fledged from 25% of the total Snowy Egret eggs laid at Georgia (Teal 1965). Breeding success could not be derived from the data given for localities other than the Salton Sea.

The clutch size of the Snowy Egret at the Salton Sea is similar to that reported by other workers. Snowy Egret egg mortality is about 10% higher at the Salton Sea than the comparable value at Lake Alice, Florida, as is Cattle Egret egg mortality at the Salton Sea compared to that found at South Africa. Cattle Egret egg mortality is also about 20% higher at the Salton Sea than in Florida. This increased mortality could be one of the first signs of reproductive problems caused by pesticide residues (discussed later). The large Snowy Egret overall mortality at Georgia is due to heavy predation pressure. Loss of one or more young from Snowy Egret broods was observed at the Salton Sea and Lake Alice, Florida, although only at Lake Alice was there strong evidence that the reduction was mainly due to starvation (Jenni 1969). Combined with the observation of seasonal decrease in clutch size, this fact fits

TABLE 20. *Percent Snowy Egret breeding mortality at the Salton Sea and other locations.*

Year	Location	Egg mortality, from laying through hatching	Nestling mortality, from hatching to fledging	Overall mortality
1974	Salton Sea, Ca.	30.9	22.7	46.6
1960[a]	Lake Alice, Florida	19.9	28.1	42.5
1955[b]	Sapelo Island, Georgia	64.6	38.7[c]	75.0

[a]Jenni (1969).

[b]Teal (1965).

[c]Table 2 in Teal (1965) has a mistake; it gives 42% nestling mortality, but from the numbers presented in the table, the mortality should be 38.7%.

Lack's hypothesis, which suggests that Snowy Egret food supply could decrease during the breeding season.

Productivity, or the number of young fledging per nest, was examined in relation to brood size (Table 14 and Table 15). The most common brood size, two for Cattle Egrets and three for Snowy Egrets, were not the most productive broods. Higher nestling mortality in larger broods did not offset the effect of larger brood size. Since nestling weights were not taken, it is not known if the young of larger broods left the nest at a lighter weight than young of smaller broods. Whether or not differential post-fledging mortality occurs in individuals from different brood sizes was also not determined. Adult Cattle or Snowy Egret mortality in relation to brood size has never been studied. A theoretical model presented by Charnov and Krebs (1974) shows how the most common, or optimal, clutch and brood size would be smaller than the most productive one, if adult mortality increased with brood size.

Cattle Egret Food Habits

The diet of the Cattle Egret is mainly insectivorous and very opportunistic, both in the Old World (Siegfried 1966a and 1971d, Feare 1975, Pomeroy 1975) and in the New World (Hanebrink 1971, Fogarty and Hetrick 1973, Foster and Tiller 1973, Jenni 1973). Adult Cattle Egrets will take almost any small creature, from insects to lizards, frogs, toads, mice, crayfish, and small birds, that they encounter while feeding. Cattle Egrets often accompany a large grazing herbivore (usually a cow), although they will also often feed in unaccompanied flocks. Dinsmore (1973) calculated that Cattle Egrets were 3.6 times more efficient when foraging with cows than when foraging alone, and Siegfried (1971b) noted that Cattle Egrets not attending cows spent 20% more time searching for food. Cattle Egrets will also follow tractors and other machinery in place of cows. In the Imperial Valley, I have often seen them feeding at the front of advancing flood-irrigation water in alfalfa fields and low row crops, as well as cattle pastures. The water evidently performs the same function of disturbing insects as do grazing cows.

Siegfried (1966a, 1969, 1971b, 1971d, and 1972a) has studied many aspects of the feeding ecology and energy metabolism of Cattle Egrets in South Africa, and has also documented the growth and food requirements of Cattle Egret nestlings in relation to the food gathering ability of the parents (Siegfried 1972c). Energy requirements of Cattle Egret nestlings are highest at the end of the second week after hatching, when feather growth reaches its maximum. During the first week of life, nestlings feed by picking food up from the nest floor, but, starting with the second week, they switch to food-grabbing, in which they reach up and violently grab the parent's bill so that the parent regurgitates directly into the nestling's distended gape. Blaker (1969, cited by Siegfried 1972c) showed that a yellow bill is a very strong releaser of feeding behavior, and stated that the function of the Cattle Egret nestling's black bill is to prevent the chicks from wasting energy and inflicting damage by attempting to eat each other. Asynchronous hatching, black bill color, the overt aggression of chicks toward their siblings at feeding times, the violent and exaggerated begging, and the feeding methods employed, all indicate behavioral strategies evolved in response to competition for food among siblings. In turn, such behavioral strategies indicate an acute food shortage during critical stages of nestling life.

In the area of South Africa studied by Siegfried, Cattle Egrets are normally successful in raising only two chicks, even if they are from a brood of three or four. Siegfried (1972c) suggests that the low success is due to their dependence upon small insects for food in man-modified habitats, and that the probably higher levels of larger prey in natural habitats might yield a more efficient return for equal foraging effort.

Table 21 presents the percentages by total volume of small invertebrates, and large invertebrates plus vertebrate prey, in the diet of nestling Cattle Egrets at the Salton Sea, Lake Alice, Florida, and Paarl, South Africa. When examining the proportion by volume of small prey items in the diet, it is obvious that the Salton Sea population is much closer to that in South Africa than to the Florida population. The Imperial Valley is desert that has been converted into agricultural land by continuous irrigation and intense management. Jenni (1973) studied heronies near low-lying wet grasslands, the agricultural improvement of which was often restricted to removal of herbaceous and woody growth. Much of the man-modified grassland habitat utilized by Cattle Egrets in South Africa consists of intensively managed, irrigated dairy pasture.

Clutch size was basically the same at both the Salton Sea and South Africa, and a seasonal decline of clutch size also occurred at both locations, whereas the

TABLE 21. *The diet of nestling Cattle Egrets from the Salton Sea, Lake Alice, Florida, and Paarl, South Africa, shown as percent of the total volume of sampled food per location.*

Food items	Salton Sea 50 food boluses % total volume	Lake Alice, Florida 50 food boluses % total volume[a]	Paarl, South Africa 98 food boluses % total volume[b]
mall invertebrates: Insecta, Arachnida, and Annelida	74.3	63.2	80.5
arge invertebrates & vertebrates: Crustacea, Fish, Reptilia, Aves, & Mammalia	25.7	36.8	19.5

[a]Jenni (1973).

[b]Siegfried (1971d).

average clutch size was much larger in Florida and no seasonal decline in size occurred. Nestling mortality from hatching to fledging (Table 19) was 3.2 to 3.6 times higher at South Africa and the Salton Sea than at Lake Alice, Florida. However, it is also possible that the low mortality for Lake Alice was due more to an expanding breeding population still filling available habitat, since by 1960 Cattle Egrets had only been breeding in the United States for about eight years; and the Lake Griffin, Florida, study done in 1971 (Weber 1975) shows nestling mortality equivalent to that found at South Africa and the Salton Sea. Still, from a comparison of data on diet and reproductive parameters, Florida appears to be a distinctly less physically stressful habitat for Cattle Egrets than either the Salton Sea or South Africa, possibly because its environment is wetter, is less man-modified, and contains a higher proportion of vertebrate prey items suitable for Cattle Egrets.

Breeding Season Initiation

Although a few Cattle Egrets started nesting two weeks earlier at the Salton Sea than at Lake Alice, Florida, the majority of early nest starts coincided with the majority of early clutches that were completed at Lake Alice (Jenni 1969). The period during which Cattle Egrets at Lake Alice initiated nesting was 4 weeks longer than that of Snowy Egrets at Lake Alice; however, the same period was 8 weeks longer at the Salton Sea for Cattle Egrets in comparison to Snowy Egrets. The prolonged period of nest initiation at the Salton Sea was probably related to renesting attempts following extensive nest failure in the first portion of the breeding season. These figures suggest that Cattle Egrets are capable of maintaining a strong nesting urge for a longer time than are Snowy Egrets.

It is possible that a brief period of rain in March may have helped stimulate early Cattle Egret breeding attempts at the Salton Sea. In Guyana, South America, many herons and egrets nest almost exclusively during the rainy season (Lowe-McConnell 1967). These rains can be quite variable in time of occurrence from year to year. Cattle Egrets are native to Africa and their breeding in the drier areas occurs during the rainy season (Siegfried 1966c). Lowe-McConnell (1967) documents the ability of Cattle Egrets to quickly initiate breeding activities with the onset of rainy periods in South America. Since their population is now high, not only do Cattle Egrets breed during the main rains (April to August), but they also breed during the year-end rains (November and December), if these rains are fairly heavy. Thus the Cattle Egret can often complete two successful breeding seasons in one year while other herons and egrets usually breed only once. Because they have relatively recently arrived from a drier habitat (Africa), Lowe-McConnell (1967) speculates that Cattle Egrets in Guyana are more easily triggered physiologically by rain to breed than are the indigenous herons.

Mackworth-Praed and Grant (1957) mention other records from Africa which show that Cattle Egrets breed during rainy periods and are quite flexible with regard to timing of the nesting season. In Nigeria they breed twice, from May to July and also in September. On equatorial Lake Victoria, where there are two rainy seasons a year, Cattle Egrets breed from March to June and again from September to October. In Egypt, breeding occurs during April and May (Spring) and in South Africa the species breeds from September or October to December (Spring) (Siegfried 1972b).

In Alabama, Dusi and Dusi (1968) documented the almost total failure of a large, mixed species heronry due to long periods of drought and heavy predation pressure from grey rat snakes, barred owls, and fish crows. Little Blue Herons, Cattle Egrets, and White Ibises were the major species present. Interestingly enough, there were two separate attempts at nesting, from the 29 April to 7 June and from the 17 July to 31 July. Both attempts were initiated after a period of rainfall, and both failed after a long drought interval.

In 1974, rain fell on only 16 days at Brawley, the weather station nearest the Salton Sea nesting area. On 4 of the 16 days, rainfall consisted of a trace and only on the 8 January did it equal 2.56 cm. Amounts of 0.15 cm on 8 March, and 0.36 cm on 9 March 1974, were recorded. However, the first Cattle Egret nest did not occur until 29 March, and the majority of early nests were built from about 16 to 20 April 1974. The next rain fell in July and was little more than a trace. Although the small amount of rain that fell in early to mid-March may have stimulated breeding activity somewhat, the nesting response occurred so much later that it is difficult to believe that these small showers triggered the major period of reproduction. Lowe-McConnell (1967) observed Cattle Egrets laying eggs within a week of heavy rain in South America. The

Salton Sea area has so little rainfall that the nesting impulse is more likely triggered by factors such as day length, direct food abundance, and, possibly, irrigation. Although this factor was not studied, irrigation could contribute to the drawn-out nesting period by providing suitable habitat for prey species further into summer and fall than would have otherwise existed, or by simulating the post-rain environmental condition of water lying on the ground.

Snowy Egret populations in southern California and Florida differ strikingly in breeding time. Snowy Egrets began nesting 9 weeks later at the Salton Sea (beginning of June) than at Lake Alice (beginning of April). It is possible that a large difference in the timing of fish availability between the two locations could have determined the difference in breeding times. Kahl (1964), in a seven-year study of the American Wood Stork in southern Florida, concluded that seasonal decline of water level in marshes (with concomitant concentration of fish populations) was one of the two most important factors affecting initiation of Wood Stork egg-laying. The other factor was low temperatures, which had an inhibitory effect. Although water levels and fish concentrations were not examined either at the Salton Sea or at Lake Alice, Florida, the amount and timing of Salton Sea water-level fluctuations would be expected to differ from that in Florida. Because there is no outflow, inflowing water from irrigation often equals or exceeds that lost by evaporation at the Salton Sea, resulting in water levels that often remain the same or increase during the dry summer.

Pesticide Effects

In England, D. A. Ratcliffe (1970) was among the first to amass evidence of a link between the widespread contamination of the environment by synthetic organic chemicals, especially the persistent chlorinated-hydrocarbon compounds used as pesticides, and the decline of the British Peregrine, Sparrowhawk, and Golden Eagle. The major factor in these declines was the high frequency of egg breakage resulting from a substantial decrease in shell thickness. Studies in North America have detailed the decline of many bird populations, some to extinction (Hickey and Anderson 1968), due to deleterious effects of persistent synthetic chemicals such as DDT and its metabolites DDE and DDD, dieldrin, and possibly the Polychlorinated Biphenyls. The greatest proportion of DDT residues found in ecosystems consists of the metabolite, DDE.

Significant species differences exist in the effects of DDT and its metabolites, especially DDE, on avian reproductive success, due to complex interactions between different ecological relationships and physiological mechanisms (Risebrough, Davis, and Anderson 1970, Stickel and Rhodes 1970). Extreme variation in residue levels between individuals of the same ecologically-vulnerable species was found by Keith (1970) with studies on White Pelicans and Western Grebes. His observations indicated that chemical contamination was not evenly distributed throughout the environment.

Both Cattle and Snowy Egrets are in the family Ardeidae, therefore possible differences in pesticide residues between them would more likely be due to differences in ecological relationships, such as feeding habits, rather than physiological mechanisms. Pesticide analysis of Snowy Egret prey (fish) or Cattle Egret prey (insects, lizards, and rodents) at the Salton Sea was not done. However, Hickey and Anderson (1968) concluded that species affected by shell thinning feed mainly at the top of a food chain, on birds or fish. North American populations of the Osprey, Bald Eagle, Peregrine Falcon, and Herring Gull have experienced reproductive failures and eggshell thinning. No evidence of thin eggshells was found for the Red-tailed Hawk, Golden Eagle, or Great Horned Owl, species which prey to a greater extent upon mammals. Moore (1967) stated that rates of DDT concentration was greatest in aquatic ecosystems. Woodwell et al. (1967) found DDT concentrations in several species of fish from an estuary in New York to range from 0.17 to 2.07 ppm wet weight. In Alaska, shrews contained DDT residues ranging from undetectable levels to 0.73 ppm oven dry weight (Lincer et al. 1970). Concentrations expressed on an oven dry weight basis would be much lower if expressed as ppm wet weight. Due to the difference in prey species, Snowy Egrets could be expected to contain higher residues of DDT and its metabolites than Cattle Egrets.

The most common and widespread effect of DDT residues on bird populations is eggshell thinning. A statistically significant correlation of increasing DDE with decreasing shell thickness has been found for Herring Gull eggs from the northeastern and midwestern United States (Hickey and Anderson 1968), Double-crested Cormorant eggs in Southern California (Gress et al. 1973), and Great Blue Heron eggs in Canada (Vermeer and Reynolds 1970, Vermeer and Risebrough 1972). This negative correlation between DDE and shell thickness is also true of Snowy Egrets at the Salton Sea.

Percentage eggshell thinning is directly correlated with DDE concentrations in eggs, which in turn is probably correlated with residue concentrations in the females' body tissues (shown for California gulls by Vermeer and Reynolds (1970)). Thus, from percentage eggshell thinning, Snowy Egrets at the Salton Sea appear to contain higher concentrations of DDE than Cattle Egrets. The same data also suggest that Cattle Egrets can withstand a higher rate of eggshell thinning than Snowy Egrets. There is a difference of only 0.8 in percentage thinning between Cattle Egret broken and hatched eggshells, while Snowy Egret broken and hatched shells show a difference between categories of 10.9. Faber et al. (1972) show a difference of 9.5% thinning between Common Egret broken and hatched shells.

The extent of reproductive failure is associated with the degree of shell thinning. Extreme examples are eggs so thin that they collapse when incubated. Total reproductive failure for Brown Pelicans and almost complete reproductive failure for Double-crested Cormorants occurred from collapsed and thin eggs in southern California during 1969 (Risebrough, Davis, and Anderson

1970). The Brown Pelican eggs had been 26% below normal in 1962 (Anderson and Hickey 1970). Lack of breeding success from eggshell flaking and high embryonic mortality of Herring Gulls in Wisconsin during 1964 was associated with an extrapolated shell-thinning of 32% (Hickey and Anderson 1968). Average shell thinning of 21% of Canadian Peregrine Falcon eggs in 1967 and 1970 occurred with a 15% decrease in hatching success and 20% decrease of nests (Berger et al. 1970). The critical limit for Peregrine Falcons is apparently 20% shell thinning (Cade and Fyfe 1970). Faber et al (1972) recorded an average 15.2% shell thinning for Common Egrets in California associated with a 24% increase of nesting attempts suffering egg loss between 1967 and 1970. Common Murres in California averaged 13% shell thinning in 1968 and 1970 with no known reproductive problems (Gress et al. 1971). My study in 1974 showed eggshell thinning in two additional species; Snowy Egrets and Cattle Egrets at the Salton Sea averaged 18.8 and 17.3% thinning for broken and hatched eggs. The only evidence of pesticide-related reproductive failure consists of the 54.6% of Snowy Egret and 23.5% of Cattle Egret nesting attempts that contained at least one damaged egg. Also, the percent damaged eggs per Snowy Egret nest was very slightly correlated with DDE.

The large discrepancy between Cattle Egret clutch size at the Salton Sea and Florida could be due in part to pesticide effects. Information on pesticide residue levels of egrets in Florida is lacking, but parts of Florida have been intensively farmed since the 1920's and 1940's (Rice 1956, Siegfried 1966c). Egg production of Coturnix Quail on dietary dosages of DDT was lower than that of untreated quail (Stickel and Rhodes 1970). However, egg production of Mallards fed doses of DDT was not reduced (Heath et al. 1969). Evidence from eggshell thinning and damage suggests that Snowy Egrets are being affected by pesticide residues at the Salton Sea to about the same degree as are Cattle Egrets. Yet, Snowy Egret clutch sizes were very similar at the Salton Sea and Florida and DDE was not correlated with total Snowy Egret eggs laid per nest, strongly suggesting that differences in Cattle Egret clutch size were due to factors other than pesticide residues.

Another possible effect of pesticide residues is delayed ovulation. Jefferies (1967) showed a significant correlation between dietary intake of DDT and delay in ovulation by Bengalese Finches. Risebrough, Florant, and Berger (1970) speculate that delayed breeding could be an environmental effect of PCB through induction of liver enzymes to degrade estradiol. It was impossible to evaluate this factor from data obtained at the Salton Sea.

The same problem exists in assessing abnormal breeding behavior accompanied by moderate or high residue levels. Incidents of refusal to incubate, systematic destruction of eggs, expulsion of live chicks, lack of advancement past the copulatory and egg laying stage, and abnormal reinitiation of the breeding cycle have been observed in the field for Grey Herons in England (Milstein et al. 1970), Great Blue Herons in California (Pratt 1973), and in the laboratory for Bengalese Finches (Jefferies 1967). No data were obtained on these phenomena at the Salton Sea, however.

Woodwell et al. (1967) suggested that pesticide residues could affect a population by increasing mortality of adults with unusually high residue levels in their tissues. Great variation in residue concentration per individual was found by Keith (1970), and Hickey (1970) suspects that adult mortality was an added factor in the rapid extirpation of the eastern Peregrine Falcon population. Four adult Common Egrets in 1970 died in convulsions, probably from dieldrin poisoning, in a California breeding colony (Faber et al. 1972). Accidental mortality or predation were the most obvious causes of deaths of juvenile or adult egrets at the Salton Sea breeding colonies. No deaths suggestive of pesticide poisoning were observed and neither the eggs nor the two juvenile Cattle Egrets analyzed for pesticides contained unduly high residue concentrations. Therefore, it is unlikely that adult mortality from high pesticide burdens in body tissues is occurring at the Salton Sea.

Although 54.6% of Snowy Egret and 23.5% of Cattle Egret nesting attempts contained at least one damaged egg and the presence of DDE was significantly correlated with thinner Snowy Egret eggshells, the effect of pesticide residues on the reproductive success of either egret species was probably slight. It does not appear that either Snowy or Cattle Egrets at the Salton Sea have yet reached the critical limit of eggshell thinning, which would be evidenced by extensive reproductive failure.

Investigator's Effect on Colonies

Although some colony disturbance was necessarily involved in this study, this disturbance was minimal. No avoidance of areas with colored tags was observed, and birds were seen to return promptly to nests that had been examined. More than 90% of the eggs collected for pesticide analysis were already damaged in some fashion and thus had a low probability of hatching successfully. Only 1.3% of all Cattle Egret eggs and 3.3% of all Snowy Egret eggs laid were collected. Occasionally, during nest examination, one or more of the nestlings would leave the nest even though they were still too young to swim well. Most of these nestlings were rescued and replaced. One did drown, however, and it is possible that some of those that moved to another location were later unable to return to their own nest. Goering (1971) and Weber (1975), in assessing the effect of careful scientific study upon heron and egret colonies, detected little difference between frequently checked nests and those checked at long intervals.

Collection of regurgitated food boluses may also have detrimentally affected the young. Young egrets will pick up food from the nest floor (Weber 1975), but

Jenni (1969) showed that collection of regurgitated food pellets had little effect on nestling survival in his study. Of the four heron and egret species nesting within that colony, there was no major difference in mortality rates between species whose young regurgitated readily and those which did not.

All banding, tagging, and dye-marking activities occurred in August, near the end of the breeding season. Siegfried (1971a) sprayed dye on Cattle Egrets at roosting areas in South Africa and did not observe ill effects or increased fear of the observer. Also, there were no readily observable differences in the Imperial Valley between treatment received by three 1973-tagged Cattle Egrets from other Cattle Egrets, and that received by untagged birds. A strong effort was made to place newly marked birds back on the correct nest, but this effort may not have been totally successful. During the breeding season I banded or marked 265 Cattle Egret young, 5 adult Cattle Egrets, and 62 Snowy Egret young. An additional 29 Cattle Egrets were banded and marked by David W. Foster (Swisher 1975). Only 4 Cattle Egret young were seen after banding and tagging activities with severe head injuries; one was dead in a nest and another had drowned. These young had probably entered nest territories that were not theirs and their head injuries were inflicted by the territory owners. More Cattle Egrets (471) were banded in 1973 than in 1974 (299) (Foster 1974), but it is possible that reproductive output was lower in 1974 due to factors other than disturbance. Such factors include increased cotton acreage, a crop which is not Cattle Egret feeding habitat, and the five continuous weeks of strong wind which caused almost total failure of early breeding attempts.

Formation of the New Colony might have been a response to disturbance since there are no records of that location having been used before, and since the population of the Old Colony had dropped to a low level. However, both colonies were still active and the population of the Old Colony was greater than that of the New Colony within a week or so of its discovery. Since the New Colony was discovered very shortly after the damaging period of strong wind at the beginning of the breeding season, an alternative view is that its formation was a result of wind-induced nest failure in the Old Colony.

Cattle Egret Range Expansion

The range expansion of the Cattle Egret in both the Old and New Worlds has been well documented (Peterson 1954, Sprunt, 1955, Haverschmidt 1957, Siegfried 1966b, Hubbs, 1968, Kuyt 1972, Zimmerman 1973, Belton 1974). Stepney and Power (1973) note that explosive range expansions are commonly associated with a species gaining access to a large tract of suitable habitat, either by the recent appearance of a new area of habitat or by the surmounting of a previous barrier.

In Africa, prior to 1875, the Cattle Egret as a permanent resident was very probably restricted mainly to the tropical and subtropical high-rainfall areas (Siegfried 1965, 1966c). At about the turn of the century, a few widely scattered permanent colonies existed in certain areas of the temperate region, which provided suitable but limited habitat along permanent rivers and other waters. Only isolated breeding colonies existed before 1920; the period from 1920 to 1940 saw an extensive spread and increase of Cattle Egrets in many different regions. Also from 1920 to 1940, the open rangeland system was replaced by fenced pastures that were planted, irrigated, and planned for rotational grazing and selective breeding. Skead (1952, cited in Siegfried 1965) proposed that the most likely cause for the marked spread and numerical increase of Cattle Egrets had been the development of water conservation and irrigation. Siegfried's (1965) data support this contention. He showed that the bird's resident distribution, especially in the transitional and semiarid areas of South Africa, was closely tied to the availability of water. Its period of residency in many of these areas could be directly related to the length of time that irrigation schemes had been in operation. The increase and spread of Cattle Egrets in Guyana, South America, was closely associated with developing pasture lands, although it was done by clearing forest rather than by irrigation (Lowe-McConnell 1967). With the advent of extensive pasture lands in Florida, Snowy Egrets were observed for the first time foraging beside cows for insects, in addition to fishing in marshes, their traditional feeding grounds (Rice 1954). When Cattle Egrets arrived in Florida, Rice (1956) noted that Snowy Egrets were poor competitors of the mainly insectivorous Cattle Egrets, and later Cattle Egret population growth in the United States was shown to generally be the exponential growth pattern expected in a species expanding into an unlimited environment (Bock and Lepthien 1976).

The Cattle Egret is a good colonizing species not only because large areas of suitable habitat were available for occupancy and it appears to possess good dispersal ability, but because it is also very adaptable. Cattle Egrets are more efficient when foraging with large grazing herbivores (Siegfried 1971b, Dinsmore 1973), but they will also follow farm and garden machinery (Dinsmore 1973, Harrington and Dinsmore 1975, and personal observation), water in irrigated alfalfa fields (personal observation), or even giant tortoises (Feare 1975). They have also been reported feeding at refuse dumps and scavenging in market places in Uganda and the Seychelles (Pomeroy 1975, Feare 1975), and on islands utilizing breeding sea bird populations. They have been noted as predators upon Sooty Tern eggs and young chicks, and as kleptoparasites of older tern chicks by chasing them until they regurgitated their last meal, which was then promptly eaten by the pursuing Cattle Egret (Harrington and Dinsmore 1975, Feare 1975).

Reproductive data from my study at the Salton Sea records the ability of the Cattle Egret to nest early, to renest, and to sustain a much longer breeding season than the Snowy Egret, which helps prevent catastrophic colony loss from heavy wind or rain storms. Weber (1972) also noted the Cattle Egrets' long breeding season, and in addition stated that they returned more rapidly to the nest than other species when an investigator was nearby. If ecological conditions are suitable, Cattle Egrets are also capable of successfully breeding twice within the same year (Mackworth-Praed and Grant 1957, Lowe-McConnell 1967). Rice (1956) suggested that Cattle Egrets were such successful colonizers because they seem to react to interspecific social stimuli; for example, arriving at new breeding colonies through associating with wintering flocks of other herons and accompanying them back to their breeding grounds, and being capable of breeding at very low numbers in mixed species heronries. This behavior presents a plausible explanation of the Cattle Egret's arrival in the Imperial Valley and successful establishment at the New River delta breeding colony. In addition to their other attributes, an analysis of South African banding data concluded that Cattle Egrets appear to have a lower first year mortality than other northern herons, possibly because the fish eaters may find it harder to perfect techniques of food capture (Siegfried 1970).

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ABSTRACT

Since about 1888, the Cattle Egret, *Bubulcus ibis*, has expanded its distributional range into South Africa, Australia, and North, Central, and South America. The species was first recorded breeding in the Imperial Valley, southern California, in 1969 at the New River delta on the Salton Sea. This colony also contained breeding Snowy Egrets, *Egretta thula*, and was intensively studied in 1974 from mid-March through September. Another colony developed in the New River delta during the breeding season, but failed due to predation, probably by raccoons. Estimated Cattle Egret populations varied during the breeding season from 750 to 6,300 birds; the maximum population that was actively breeding was approximately 1,480 birds. Estimated Snowy Egret active breeding population was approximately 308 birds; the population ranged from less than 50 to 500 birds. Evidence is presented for late summer movement of Cattle Egrets into the Imperial Valley.

The breeding season was arbitrarily divided into two parts, based on two general peaks in nesting activity. Snowy Egrets bred seven weeks after the first Cattle Egrets, during the second part of the season.

Cattle Egret reproductive success was very low in the first part of the breeding season because of several periods of continuous high winds. Cattle Egret mean clutch size was 2.58 eggs and that for Snowy Egrets was 3.96 eggs. Both species showed a seasonal decrease in clutch size. Snowy Egrets had a significantly higher percentage of damaged eggs than did Cattle Egrets. Both species had the same percentage success in hatching and fledging, taking into consideration the larger Snowy Egret clutch. Cattle Egrets hatched 2.04 eggs and fledged 1.86 young per successful nest; Snowy Egrets hatched 3.10 eggs and fledged 2.90 young per successful nest. Cattle Egret nestling diet was, by volume, 53.0% insects, 18.5% spiders, 12.5% mice, and 16.0% of combined crawfish, earthworms, fish, and lizards. Snowy Egret diet was almost exclusively fish. Data from both hatched and broken eggs showed 17.3% thinning for Cattle Egrets and 18.8% for Snowy Egrets. The amount of thinning increases to 21.8% for Snowy Egrets when only broken eggs are considered. Residues of DDE, DDT, DDD, dieldrin, and PCB were found in Snowy Egret eggs, but only DDE was significantly correlated with decrease in eggshell thickness. Cattle Egret eggs were collected, but are not yet analyzed. During 1974, 132 juvenile and 5 adult Cattle Egrets were banded, wing tagged, and marked with picric acid dye. An additional 136 juvenile Cattle Egrets were banded and marked with dye, and 66 juvenile Snowy Egrets were banded.