NESTING SUCCESS OF COMMON EGRETS AND GREAT BLUE HERONS IN THE SAN FRANCISCO BAY REGION

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A study of the breeding biology of Great Blue Herons (*Ardea herodias*) and Common Egrets (*Casmerodius albus*) was started in 1967 at Audubon Canyon Ranch, Marin County, California, where both species nest in the same heronry. I have reported on results of the first 2 years (1967, 1968) of the study (Pratt 1970). This paper presents findings on nesting success for 1969 and 1970 and adds data on clutch size for all 4 years. To facilitate comparison of nesting success with the 2 prior years, I include some previously published data.

There are few other studies of nesting success of these species. Vermeer (1969), Wilburn (1970), and Page (1970) reported on nesting success of the Great Blue Heron. Teal (1965) and Page (1970) did so for the Common Egret. Owen's (1960) study of nesting success of the Gray Heron (*Ardea cinerea*) in England offers valuable comparative information.

METHODS

A detailed description of the study area is given in the previous report (Pratt 1970). The birds nest in the tops of 80–100 ft Coast Redwoods (*Sequoia sempervirens*) but can be easily observed with binoculars and spotting scopes from an overlook on the canyon wall.

As nests were constructed, they were plotted and numbered on a panorama of the heronry drawn from a photograph. They were then observed at least twice a week, sometimes more often, and a chronological record was kept until they were abandoned. All observations were made with 7 × binoculars and 20 × spotting scopes. Observations were started on 25 March 1967, 6 January 1968, and 1 February 1969 and 1970, and were concluded when the last fledglings abandoned the nest on 12 September 1967, 4 September 1968, 29 July 1969, and 20 August 1970. All-day observations on one egret nest during incubation were taken by a team of observers on 2 April 1968 from 05:35 to 18:35 PST and on three egret nests during incubation on 4 April 1969 from 05:00 to 19:00 PST.

RESULTS

ESTIMATE OF COMMON EGRET BREEDING PAIRS

To arrive at an estimate of the number of breeding pairs of egrets, I plotted the course of each nest by date of establishment, using a color code to indicate changes in breeding activity. It was common in all years of the study to observe two nesting attempts in continuously occupied nests presumably by the same breeding pair. In five nests, there were three attempts and, in 1970, four were made in one continuously occupied nest. Since replacement clutches were observed in continuously occupied nests, it seemed probable that some unsuccessful pairs abandoned their nests after an early failure and built again in another location for a later attempt. Thus nests started after the dates of early failures were considered second attempts by previously unsuccessful pairs. I assumed that nests established after 17 May 1967, 20 April 1968, and 1 May 1969 and 1970 were renestings.

There was a close correspondence between early failures and late starts. The estimate of breeding pairs was also in close agreement with the number of nests known to be occupied simultaneously. In 1967, 91 nests were plotted, 21 were late starts, 23 were abandoned early, and 69 were known to be occupied simultaneously. In 1968, 114 were plotted, 43 were abandoned early, 40 were started late, and 74 were occupied simultaneously. In 1969, 116 were plotted, 29 were abandoned early, 30 were started late, and 85 were occupied simultaneously. In 1970, 137 were plotted, 55 were abandoned early, 52 were started late, and 85 were occupied simultaneously.

The number of nests plotted is less than the number of nesting attempts in 1967, 1969, and 1970 (table 1) because, for purposes of estimating breeding pairs, a continuously occupied nest was counted only once though there may have been more than one attempt in it. In 1968, the nests plotted exceed the number of nesting attempts because four nests of unknown results and eight nests that were occupied without laying were not included in the analysis of nesting attempts.

I estimated 70 breeding pairs in 1967, 74 in 1968, 86 in 1969, and 85 in 1970.

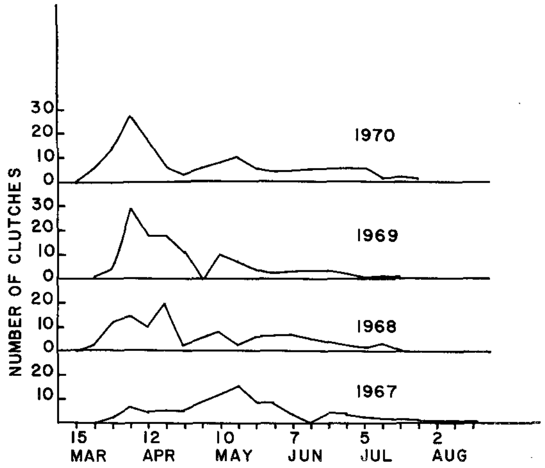

FIGURE 1. The number of Common Egret clutches started per week for the years 1967 through 1970.

COMMON EGRET LAYING SEASON

First clutches were started between 15 and 24 March in each year. The pace of laying as measured by the number of clutches started per week varied from year to year, being slowest in 1967 (fig. 1). An unusually wet April probably accounted for the lag in that year (Pratt 1970). The spread between laying by first and last arrivals was about 8 weeks in 1967, 5 weeks in 1968 and 1969, and 6 weeks in 1970. Last clutches were started in the first week in August in 1967, first week in July in 1968 and 1969, and second week in July in 1970.

COMMON EGRET NESTING SUCCESS

The number of egret fledglings raised per breeding pair declined from 1.4 in 1967 to 1.1 in 1968 and 1.0 in 1969 and 1970. The decline in success in 1968 was largely the result of greater nestling loss (table 1). The continued low success in 1969 was due to greater egg loss and more hatching failures. In 1970, the low success was primarily the result of an additional sharp rise in egg loss. The estimate of breeding pairs was about the same in 1969 as in 1970, but the total number of nesting attempts losing eggs increased from 47 to 83. Fewer hatching failures in 1970 were probably an indirect result of the increase in egg loss.

TABLE 1. Outcome of Common Egret nesting attempts.

	1967	1968	1969	1970
Number of attempts	96	109	120	154
Per cent successful[a]	52	41	33	28
Per cent losing eggs[b]	30	34	39	54
Per cent losing nestlings[c]	8	17	11	10
Per cent hatching failure[d]	9	7	13	3
Per cent laying failure[e]			4	5

[a] Successful attempts raised at least one fledgling.
[b] Attempts losing eggs lost all eggs before incubation was complete.
[c] Attempts losing nestlings lost all nestlings.
[d] Hatching failures incubated eggs 5 weeks or more without hatching.
[e] Laying failures built and occupied nests 2 weeks or more without laying; not included in the analysis in 1967 and 1968.

TABLE 2. Number raised in successful Common Egret nests.

	1967	1968	1969	1970
Number of successful nests	50	41	40	43
Per cent raising one	37	32	25	30
Per cent raising two	33	61	28	49
Per cent raising three	30	7	45	21
Per cent raising four	0	0	2	0
Number raised per successful nest	2.1	1.8	2.3	1.9
Per cent nestling mortality	19	43	24	34

Breeding pairs that fledged at least one young egret declined from 75% in 1967 to around 50% in 1969 and 1970.

The number of young egrets fledged per successful nest ranged from 1.8 in 1968 to 2.3 in 1969 (table 2). This measure of success varied independently from the number raised per breeding pair. Successful pairs in 1969 were more productive than in any other year though success per breeding pair was only 1.0. In that year, 45% of the successful nests raised three young, and one nest raised four. In 1968, when the number raised per successful nest was lowest, only 7% of the successful nests raised three young.

EGRET EGG LOSS

There was an increase in per cent of egret nesting attempts that failed because of egg loss from the first to the fourth year of the study (table 1). Perhaps the most important factor in egg loss was breakage in the nest. Observers reported egrets "throwing" eggs out of the nest in every year of the study. In 1970, I saw the following incidents of broken or dented egret eggs. On 28 March, about 6 days after laying, one of two eggs in nest 56 had two dents in it. Two days later this egg was gone; the remaining egg hatched. On 2 April, the egret in nest 97 threw a broken eggshell out of the nest and picked out bits of material and shook them off its bill. I saw no swallowing motions or other behavior which would indicate that the adult was eating the contents of the egg. Two more eggs were laid, but by 10 April one of them had an obvious dent in it. By 14 April the nest was gone. On 10 April in nest 92, the egret methodically and apparently purposefully rolled one of four eggs out of the nest. The egg seemed intact, but there might have been small cracks that I could not see. On 14 April only one egg was left and by 20 April the nest was abandoned. On 20 April in nest 100, the adult flipped one broken egg from a clutch of two out of the nest. It seemed to ignore embryo remains in the nest. Four days later this nest was abandoned.

Successive egg loss in a pattern suggestive of breakage in the nest occurred in 13 nests with complete clutches in 1970. Eggs were lost from many other nests before the clutch was completed. The adults often remained at the nest after all eggs were lost. Some pairs started replacement clutches, some abandoned the nest after a few days, some lingered as long as 4 weeks without further laying.

A common though less frequent pattern of egg loss was abandonment of the clutch. This often occurred after almost 4 weeks of incubation or at about the time hatching would be expected. The reason for these desertions is unknown.

Replacement clutches started in late June and July were not incubated to hatching. These accounted for a small number of failures due to egg loss each year and may be the result of desertion by the adults due to lateness of the season.

For other heronries, predation has been reported as a major factor in egg loss (Jenni 1969; Teal 1965; Dusi and Dusi 1968; Taylor and Michael 1971). There was no evidence, however, that predators caused significant egg loss at Audubon Canyon Ranch. Egg predation seen was limited to Common Crows (*Corvus brachyrhynchos*) and Steller's Jays (*Cyanocitta stelleri*) pecking eggs in abandoned nests. In the all-day observations of four egret nests during incubation, adults on the nests did not leave until they were relieved by their mates. Occasionally, I have since seen an incubating egret leave the nest briefly to collect a twig from a nearby tree and return with it to the nest. These trips were too brief to allow a predator to take the eggs. Thus in the normal course of incubation, eggs were guarded constantly. The crows and jays observed eating eggs were presumably scavengers taking advantage of deserted nests. The possibility of nocturnal predation by mammals exists but no direct evidence was found. The 80- to 100-ft height of the nests from the ground probably deters most mammalian predators, and since the adults attended the nests constantly during the day, they probably did the same at night and could protect the eggs.

TABLE 3. Outcome of Great Blue Heron nesting attempts.

	1967	1968	1969	1970
Number of attempts	61	69	55	58
Per cent successful[a]	56	74	87	66
Per cent losing eggs[b]	11	9	4	17
Per cent losing nestlings[c]	31	13	5	14
Per cent hatching failure[d]	2	4	4	3

[a] Successful attempts raised at least one fledgling.
[b] Attempts losing eggs lost all eggs before incubation was complete.
[c] Attempts losing nestlings lost all nestlings.
[d] Hatching failures incubated eggs 5 weeks or more without hatching.

COMMON EGRET CLUTCH SIZE

In a sample of 87 egret nests including nests from each of the 4 years, there were 8 nests with 2 eggs, 57 with 3 eggs, 20 with 4 eggs, and 2 with 5 eggs. The average clutch had 3.2 eggs. Since the nests were not seen every day, and since there was considerable egg loss, eggs could have been lost between visits and hence clutch size could be underestimated. I attempted to compensate for this by including in the sample only those nests in which the clutch size remained at a constant maximum for several observations.

Hatching success in this sample was 60%. Overall hatching success was lower since the sample excluded clutches that lost eggs before the clutch was complete.

GREAT BLUE HERON NESTING SUCCESS

I estimated the number of breeding pairs for the herons in the same way as for the egrets. In 1967, 59 nests were plotted, 12 were abandoned early, 9 were started late, and 49 were occupied simultaneously. In 1968, 68 nests were plotted, 8 were abandoned early, 6 were started late, and 61 were occupied simultaneously. In 1969, 55 were plotted, 5 were abandoned early, none was started late, and 55 were occupied simultaneously. In 1970, 55 were plotted, 9 were abandoned early, 5 were started late, and 49 were occupied simultaneously.

I estimated 50 breeding pairs of herons in 1967; 62, in 1968; 55, in 1969; and 50, in 1970. The number of fledglings raised per breeding pair was 1.5 in 1967 and 1970, 1.7 in 1968, and 2.0 in 1969 (table 3). There was no consistent trend in nesting success during the 4 years.

The number of young raised in successful nests ranged from 1.9 to 2.3 (table 4). Vermeer (1969) found an average success of 2.5 per nest for Great Blue Herons in Alberta,

TABLE 4. Number raised in successful Great Blue Heron nests.

	1967	1968	1969	1970
Number of successful nests	34	50	48	38
Per cent raising one	24	14	14	29
Per cent raising two	50	64	42	47
Per cent raising three	26	22	42	24
Per cent raising four	0	0	2	0
Number raised per successful nest	2.2	2.1	2.3	1.9
Per cent nestling mortality	45	30	19	40

Canada, in 1967 and 2.2, in 1968. Wilburn (1970) reported an average success near Lincoln, California, of 2.6 in 1970 and Page (1970) reported a success of 2.8 near Los Banos, California. Thus the herons were somewhat less successful at Audubon Canyon Ranch than in the other areas. Owen (1960) found even wider variations in nestlings raised by the Gray Heron in England for different years and in different heronries. He was able to relate these variations to differences in the amount of food available to the nestlings.

GREAT BLUE HERON CLUTCH SIZE

In a sample of 53 heron nests, there were 30 clutches of 4 eggs, 22 of 3 eggs, and 1 of 5 eggs. Average clutch size was 3.6. Hatching success in this sample was 86%.

NESTLING MORTALITY

Nestling mortality including losses of whole broods as well as losses within broods ranged from 19% to 43% for the egrets (table 2) and 19% to 45% for the herons during the 4 years (table 4). Losses within broods were largely due to starvation of younger, smaller chicks. During feedings, nestlings of both species frequently attacked smaller siblings viciously and sometimes drove them to the edge of the nest, thus preventing them from feeding. The difference in size between larger and smaller siblings often increased until the smaller died.

Although some nestlings suffered accidental death, this was not a significant cause of mortality. One half-grown heron nestling was found dead with a broken wing. The body of another 2-day-old heron nestling had a triangular piece of fish bone measuring 30 mm × 22 mm × 20 mm lodged in its esophagus. A sharp corner had pierced the esophagus and gone through the outer skin.

A variety of factors, some unknown, contributed to losses of whole broods. The loss of many entire heron broods in 1967 was associated with persistent rainfall in April (Pratt 1970), but the herons compensated in part by successful renestings. One heron brood died possibly due to disease or parasite overload.

Both herons and egrets lost broods that hatched very late in the season. Bodies of nestlings remained in these nests with no evidence of predation. They were probably deserted by the adults.

Predators took some nestlings. In two nests in 1969 and 1970, I saw freshly bloodied bodies of young egrets old enough to be left by the parents but too young to fly. The nest platforms were intact. Nocturnal predation seemed most probable. Circumstantial evidence implicated predation by Great Horned Owls (*Bubo virginianus*) on adult Great Blue Herons (Cottrille and Cottrille 1958), young Osprey (*Pandion haliaetus*) (Reese 1970), and on young Red-tailed Hawks (*Buteo jamaicensis*) (Luttich et al. 1971.) Great Horned Owls have been heard calling at Audubon Canyon Ranch on numerous occasions and might have caused some nestling loss.

DISCUSSION

EGG LOSS AND SHELL-THINNING

The low egret reproductive success, the increased egg loss, the fragility of eggshells found under the nests, and sight records of broken eggs in the nests suggested that the breeding birds were laying abnormally thin-shelled eggs.

Species of fish-eating birds for which shell-thinning has been detected include the Herring Gull (*Larus argentatus*), (Hickey and Anderson 1968), White Pelican (*Pelecanus erythrorhynchos*) and Double-crested Cormorant (*Phalacrocorax auritus*) (Anderson et al. 1969), Common Murre (*Uria aalge*) (Gress et al. 1971), Gray Heron (Prestt 1969), Brown Pelican (*Pelecanus occidentalis*) (Blus 1970; Anderson and Hickey 1970), and Great Blue Heron in Canada (Vermeer and Reynolds 1970). The relationship between shell-thinning and high levels of chlorinated hydrocarbons, especially DDE, in the bodies and eggs of affected birds is by now well known. It seemed appropriate, therefore, to examine the Common Egret eggshells for evidence of thinning and if possible analyze egg contents for chlorinated hydrocarbons.

Shell samples were collected from the floor of the heronry at Audubon Canyon Ranch in 1970. Shell thickness was measured and compared with museum specimens collected before 1947, the date that marked the beginning of the accumulation of chlorinated hydrocarbons in the environment and also the start of marked shell-thinning in other raptorial and fish-eating species. Egret shells averaged 15.2% thinner than museum specimens. Hatched egret shells averaged 7.8% thinner; those apparently broken in the nest averaged 17.3% thinner. Heron eggshells averaged 10.4% thinner than pre-1947 shells. Hatched heron shells averaged 7.8% thinner; those broken in the nest averaged 17.2% thinner (Faber et al. 1972).

It was not possible to collect whole eggs from the nests at Audubon Canyon Ranch. However, one egret shell, two heron shells, and one unidentified shell found on the floor of the heronry contained enough yolk for analysis. DDE residues ranged from 100 ppm to 300 ppm in the lipid. Bodies of five adult Common Egrets found dead on the floor of the heronry were also analyzed for pesticides. Mean DDE residues in the livers on a wet-weight basis were 124.3 (Faber et al. 1972). These levels are comparable to those found for other species with thin eggshells.

Heron egg loss was considerably less than egret egg loss and heron shells on the average were not as thin as egret shells, though both species use a common feeding ground at Audubon Canyon Ranch. Differences in food habits may help explain this difference in amount of shell-thinning. Although both species feed largely on fish, herons eat small rodents as well (Palmer 1962). Since rodents are at a lower trophic level than fish, they would be expected to contain smaller amounts of pesticides and thus the heron diet might be less heavily contaminated. In addition, both species are migratory in this part of their range. They do not necessarily winter in the same areas and consequently may receive different exposures prior to their arrival at the heronry. Interspecific differences in susceptibility to shell-thinning may be a factor as well. Bitman et al. (1969) found individual differences in susceptibility to chlorinated hydrocarbon-induced shell-thinning in Japanese Quail and it seems possible that there may also be interspecific differences.

A rise in heron egg loss in 1970, though not large (table 3), when considered in light of the measured shell-thinning, could be more than a chance fluctuation. It may indicate a rise in the number of thin-shelled eggs broken during incubation.

POSSIBLE SIGNIFICANCE OF LAYING FAILURES

I added laying failures to the analysis of egret nesting success in 1969 and 1970 for the sake of completeness and to establish a base for comparison in future years. The cause of these laying failures is unknown but two possibilities should be considered. First, in many species including the Gray Heron, young birds may build and occupy nests without laying (Owen 1959). Thus some of the egrets that failed to lay eggs may have been young birds.

Second, laying failure in a declining population of Peregrine Falcons (*Falco peregrinus*) was suspected to be the result of contamination by DDT (Hickey 1969:260). As mentioned above, bodies of dead adult egrets found on the floor of the heronry in 1970 contained significant amounts of chlorinated hydrocarbons. Although there were few laying failures in this colony of egrets between 1967 and 1970, increases might indicate changes in reproductive capacities of the birds due to pesticide contamination or changes in age ratios of the population.

CHRONOLOGY OF EGRET LAYING

The discovery that doses of DDT can cause a lag in ovulation (Jefferies 1967; Bitman et al. 1969) has led to speculation that populations of birds subject to pesticide contamination might show a delay in breeding. High levels of DDE in the egret egg yolk and pesticide residue in dead adults prompted an examination of the chronology of the egret laying season for evidence of unusual delays. The pace of laying varied somewhat from year to year, but it was markedly delayed only in 1967 (fig. 1). An unusually cold, wet April explains the lag in that year (Pratt 1970). The length of the egret laying season, extending into July and even into August in 1967, can be explained as the consequence of early nesting failures followed by re-laying. The possibility cannot be excluded, however, that a few of the late clutches were first attempts by birds with unnaturally delayed ovulation. If this is so, my estimate of breeding pairs is somewhat low and nesting success per breeding pair too high.

CLUTCH SIZE AND LATITUDE

In many species, clutch size increases with latitude (Lack 1954). Common Egret clutches in the West Indies, between 16°N and 24°N, are two to three eggs (Bond 1961). Simmons (1959) indicated a clutch size of 2.9 at Avery Island, Louisiana, 30°N. Clutch size was 3.1 at Sapelo Island, Georgia, 32°N (Teal 1965). Gersbacher (1939) reported four or five eggs in a clutch in Tennessee, 36°N. Clutch size at Audubon Canyon Ranch, 38°N, was 3.2 and clutch size near Los Banos, California, 37°N, was also 3.2 (Page 1970). The clutch size in Tennessee at 36°N seems larger than clutch size in central California at 37°N and 38°N. This suggests that factors in addition to latitude may influence clutch size or as indicated above, egg loss may have reduced apparent clutch size in the California samples. In Oregon, about 43° to 44°N, clutch size is three to six (Gabrielson and Jewett 1940).

Great Blue Heron clutch size at Audubon Canyon Ranch, 38°N, was 3.6. It was also 3.6 near Los Banos, California, 37°N (Page 1970). Miller (1943) found an average clutch size of 4.3 near Philadelphia, 40°N. Vermeer (1969) found average clutch size of 5.0 at Dowling Lake, Alberta, Canada, 52°N.

Thus the available data indicate a tendency for clutch size to increase with latitude for both species.

SIGNIFICANCE OF EGRET REPRODUCTIVE RATE FOR POPULATION TRENDS

On the basis of banding returns from Common Egrets banded largely in Mississippi, Kahl (1963) calculated that egret pairs had to fledge 2.92 young per nest to maintain the population at a constant level. If this calculation is valid for West Coast egrets, the reproductive rate at Audubon Canyon Ranch is dangerously low. To fledge 2.92 young from an average clutch of 3.2 eggs would require extremely high nesting success. It seems doubtful that the Audubon Canyon Ranch egrets, even under the most favorable conditions, could achieve this. In Georgia, Common Egrets raised 44 young in 43 nests studied by Teal (1965). Although this apparently did not include possible successful renesting, it also seems unlikely that the Georgia egrets could have raised 2.92 young per nest.

The breeding population of Common Egrets at Audubon Canyon Ranch did not decline between 1967 and 1970. Further studies of population trends and reproductive success at this and other heronries are needed.

SUMMARY

Nesting success of Common Egrets and Great Blue Herons was compared for the 4 years from 1967 to 1970 at Audubon Canyon Ranch, California. The number of young raised per breeding pair of Common Egrets declined from 1.4 in 1967 to 1.0 in 1969 and 1970. The proportion of egret nesting attempts losing eggs increased in successive years from 30% in 1967 to 54% in 1970. Eggs breaking in the nest during incubation was the major cause of egg loss. The mean number of chicks raised per successful nest did not decline but rather ranged from 1.8 to 2.3 for the 4 years.

The mean number of young raised per breeding pair of Great Blue Herons ranged from 1.5 to 2.0. There was no consistent trend in nesting success for the herons. Heron pairs in successful nests raised from 1.9 to 2.3 young per nest.

These results were discussed in light of effects of possible contamination by chlorinated hydrocarbons.

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