BREEDING OF GREAT BLUE HERONS AND GREAT EGRETS AT AUDUBON CANYON RANCH, CALIFORNIA, 1972-1973

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Great Blue Herons (*Ardea herodias*) and Great Egrets (*Casmerodius albus*) are among the species known to have suffered eggshell thinning as a result of accumulating high levels of DDT and its derivatives in their body tissues (Vermeer and Reynolds 1970, Henny and Bethers 1971, Faber et al. 1972). Great Egret reproductive success in the San Francisco Bay region was recently diminished because eggs broke during incubation (Pratt 1972a) while the effect of eggshell thinning on reproductive success of Great Blue Herons was insignificant.

In 1972 the Environmental Protection Agency imposed an almost total ban on use of DDT, but even before this there were local restrictions on its use. The study reported on here has continued without interruption since 1967, allowing a comparison of reproductive success in these two affected species before and after restrictions on use of DDT.

This paper presents observations on nesting success, population levels, laying dates and clutch size of Great Blue Herons and Great Egrets during the 1972 and 1973 nesting seasons at Audubon Canyon Ranch near Stinson Beach, Marin County, California. I reported results for the earlier years elsewhere (Pratt 1970, 1972a, 1972b). Relevant data from the first five years of the study are included here for comparison. Nesting success of Great Blue Herons has been reported for Canada (Vermeer 1969, McAloney 1973) and for Oregon (Henny and Bethers 1971). Teal (1965) reported on nesting success of Great Egrets in Georgia.

The study area and methods are unchanged since my earlier descriptions (Pratt 1970, 1972a) and for the sake of brevity I shall not repeat them here. Readers may consult the publications referred to for details.

RESULTS AND DISCUSSION

Great Blue Heron

Table 1 summarizes Great Blue Heron breeding success for the seven years. In 1972 the number of young fledged per breeding pair increased to 1.7 from the low of 1.3 in the previous year. The percent of successful nesting attempts increased and the proportion of attempts that lost all the eggs dropped to 14% from the high of 27% in 1971. The number fledged per successful nest increased from 2.0 in 1971 to 2.2.

Table 1. Results of Great Blue Heron nesting at Audubon Canyon Ranch, California, from 1967 through 1973. 1. Successful attempts fledged at least one young bird. 2. Attempts losing eggs lost all eggs before any hatched. 3. Attempts losing nestlings lost all nestlings. 4. Hatching failures were clutches incubated 5 weeks or more without hatching. 5. Laying failures were pairs that built and occupied nests 2 weeks or more but never laid eggs; this category was not included in the analysis in 1967 and 1968.

	1967	1968	1969	1970	1971	1972	1973
Estimate of breeding pairs	50	62	55	50	44	46	58
Number fledged/breeding pair	1.5	1.7	2.0	1.5	1.3	1.7	1.5
Number of nesting attempts	61	69	55	58	56	50	67
% attempts successful[1]	56	74	87	66	54	72	63
% attempts losing eggs[2]	11	9	4	17	27	14	15
% attempts losing nestlings[3]	31	13	5	14	9	6	15
% hatching failures[4]	2	4	4	3	5	2	7
% laying failures[5]	—	—	0	0	5	2	0
% unknown failures	0	0	0	0	2	2	0
Number of successful attempts	34	50	48	38	30	36	42
% successful nests fledging one	24	14	14	29	23	14	21
% successful nests fledging two	50	64	42	47	60	56	52
% successful nests fledging three	26	22	42	24	13	28	26
% successful nests fledging four	0	0	2	0	3	2	0
Number fledged/successful nest	2.2	2.1	2.3	1.9	2.0	2.2	2.0

Egg loss remained at the same level in 1973, but the average number of fledglings per breeding pair declined to 1.5 and the number fledged per successful nest declined to 2.0. Successful nesting attempts were 9% fewer largely because of an increase in the proportion of attempts that lost nestlings. The fact that in four nests all chicks in the brood died at about the same time although the adults were still in attendance suggests that an increase in disease or massive parasitic infestation may have contributed to the increased nestling loss. Hatching failures reached a seven-year high of 7% in 1973 but this factor remained relatively unimportant to overall nesting success.

The estimated number of breeding pairs at Audubon Canyon Ranch ranged between a high of 62 in 1968 and a low of 44 in 1971. There were 46 pairs in 1972 and in 1973 the population increased to 58 pairs. Clearly the level of the breeding population did not fluctuate in parallel with nesting success. Since herons probably begin to breed when they are two years old (Bent 1926) and 1969 was the most successful year for the herons, if there were a direct relationship between nesting success and the subsequent number of breeding pairs one would expect an increase in the population in 1971. Instead, a drop to 44 pairs occurred. Nor can the increase in breeding pairs in 1973 be explained as the re-

sult of a prior highly successful year. Nesting success was unusually low in 1971, the year that would be expected to contribute new breeding adults in 1973. A similar lack of correspondence between breeding success and the subsequent number of breeding pairs has been found for other species, notably the White Stork (*Ciconia ciconia*) (Lack 1966: 227-228). Barring extreme nesting failures, mortality during migration and on the wintering grounds may affect the size of the breeding population in any given year to a greater extent than previous reproductive success.

Heron movements may also affect the size of breeding colonies. Lack (1954) suggests that some switching of individual pairs of herons occurs between colonies from year to year. Heronries may also be deserted or move (Lowe 1954, Carriger and Pemberton 1908, Fahey 1968, Mehner 1952, Vermeer 1969). In a statewide survey of heronries conducted from 1969-1971 by the California State Department of Fish and Game, only 32 of the 109 active heronries reported in 1971 had a history of nesting activity over the three years of the study (Mallette 1972). Three of the heronries active in 1971 were reported as inactive in 1969 or 1970.

Not far from Audubon Canyon Ranch were two small active heronries in 1973, one about 38 km northwest on the shore of Schooner Bay and another about 40 km north near Marshall on Tomales Bay. During the last 10 years, Great Blue Herons established colonies at these heronries that grew from 1 or 2 nests to 10 or 15 in 1972 and 1973. The decline in breeding pairs at Audubon Canyon Ranch from 1968 to 1973 may have been balanced by growth at these colonies. At another heronry about 18 km north near the Point Reyes National Seashore headquarters at Olema, there were between 19 and 24 nests occupied by Great Blue Herons in 1972 (R. M. Brown pers. comm.) but no herons returned in 1973. At still another site on the shore of Tomales Bay about 3 km north of the Olema heronry, local residents report between 5 and 10 active heron nests in 1972. A large tree that may have held the nests blew down the following winter. There was no trace of old nests or breeding herons in the spring of 1973. The breeding population of herons at Audubon Canyon Ranch may have been increased in 1973 by the addition of herons from these deserted colonies, but since none of the birds was marked this speculation can not be verified.

Great Egret

The most successful year for the Great Egrets was 1972 when they raised 1.5 young per breeding pair (Table 2). Successful nesting attempts reached a high of 63%, nestling loss was low, and the percent of nesting attempts that lost eggs dropped sharply. In 1970 when egg loss was most frequent, many eggs broke in the nest during incubation (Pratt 1972a). Measurements of eggshells confirmed that the egrets were laying thin-shelled eggs (Faber et al. 1972). Although eggshells were not

measured in 1972, the lower percent of attempts that lost eggs suggests that the egrets made considerable recovery from eggshell thinning in that year. Egg loss remained at the same relatively low level in 1973.

In 1973 egret nesting success declined to 1.2 fledglings per breeding pair. Successful nesting attempts dropped to 50% and attempts that lost all nestlings reached a high of 19%. Part of the percentage increase in nestling loss was an indirect result of the decline in egg loss. Since fewer late attempts lost eggs, more young hatched late and were then deserted by the adults in July about the time that chicks from successful nests departed. In addition, more chicks than usual died early in the season in nests where adults remained in attendance. It appeared that the egret chicks were affected by the same mortality factor that caused a rise in heron nestling loss.

The proportion of egret nests able to raise 3 young fell from 19% in 1972 to 9% in 1973. In part this resulted from reduced hatching success in 1973. In a sample of 46 nests with known clutch size in 1972, 83% of the eggs hatched. In a similar sample of 42 nests in 1973, 76% of the eggs hatched. Consequently the number of known broods of 3 or 4 fell from 39 in 1972 to 29 in 1973. Smaller clutches were not responsible for the decline since mean clutch size for the samples in both years was 3.0 (Table 4).

A second factor contributing to the drop in percent of nests raising 3 young in 1973 was the large proportion of broods of 3 that lost all the chicks. Only 2 broods of 3 failed completely in 1972 but 10 failed completely in 1973. Normal losses within broods left only 6 nests in 1973 able to produce 3 young. Since the percent of attempts raising 2 was high in 1973, the average number raised per successful nest of 1.9 was about the same as the 2.0 raised per successful nest in 1972.

The estimate of breeding pairs of egrets increased in 1972 to 96 from the level of about 85 during the preceding 3 years. Movements of Great Egret breeding populations make determination of the status of the population as difficult as it is for the Great Blue Herons. Two examples have recently been reported from central California. At Bair Island in south San Francisco Bay, 75 Great Egret nests were reported in 1967 but none were there in 1969 or 1971 (Gill 1972). At a San Joaquin River heronry in Merced County a Great Egret colony grew from 2 nests in 1966 to 50 in 1970 but in 1971 there were none (Page 1971). It would be unjustified therefore, to assume that the results at Audubon Canyon Ranch are necessarily indicative of general population trends.

Timing of Laying and Clutch Size

In the seasons from 1968-1970 Great Blue Heron clutch initiation proceeded rapidly once it started (Figure 1). Laying dates for 1967 were omitted from the analysis because observations did not commence

Table 2. Results of Great Egret nesting at Audubon Canyon Ranch from 1967 through 1973. For description of categories see Table 1.

	1967	1968	1969	1970	1971	1972	1973
Estimate of breeding pairs	70	74	86	85	85	96	99
Number fledged/breeding pair	1.4	1.1	1.0	1.0	1.1	1.5	1.2
Number of nesting attempts	96	109	120	154	124	114	129
% attempts successful	52	41	33	28	40	63	50
% attempts losing eggs	30	34	39	54	41	23	22
% attempts losing nestlings	8	17	11	10	13	8	19
% hatching failure	9	7	13	3	6	4	8
% laying failure	–	–	4	5	1	0	0
% unknown failure	0	0	0	0	0	2	1
Number of successful attempts	50	41	40	43	49	72	64
% successful nests fledging one	37	32	25	30	33	16	23
% successful nests fledging two	33	61	28	49	45	65	67
% successful nests fledging three	30	7	45	21	20	19	9
% successful nests fledging four	0	0	2	0	2	0	0
Number fledged/successful nest	2.1	1.8	2.3	1.9	1.9	2.0	1.9

Table 3. Frequency of Great Blue Heron clutch sizes at Audubon Canyon Ranch from 1967 through 1973.

	2 EGGS	3 EGGS	4 EGGS	5 EGGS	SAMPLE	MEAN
1967		5	4	1	10	3.6
1968		5	10		15	3.7
1969		6	8		14	3.6
1970		6	8		14	3.6
1971	3	6	3		12	3.0
1972	1	7	4		12	3.3
1973		24	7		31	3.2

Table 4. Frequency of Great Egret clutch sizes at Audubon Canyon Ranch from 1967 through 1973.

	2 EGGS	3 EGGS	4 EGGS	5 EGGS	SAMPLE	MEAN
1967	2	10	5		17	3.2
1968	1	13	3	1	18	3.2
1969	3	19	6	1	29	3.2
1970	2	15	6		23	3.2
1971	6	40	5	2	53	3.1
1972	7	26	9		42	3.0
1973	6	34	6		46	3.0

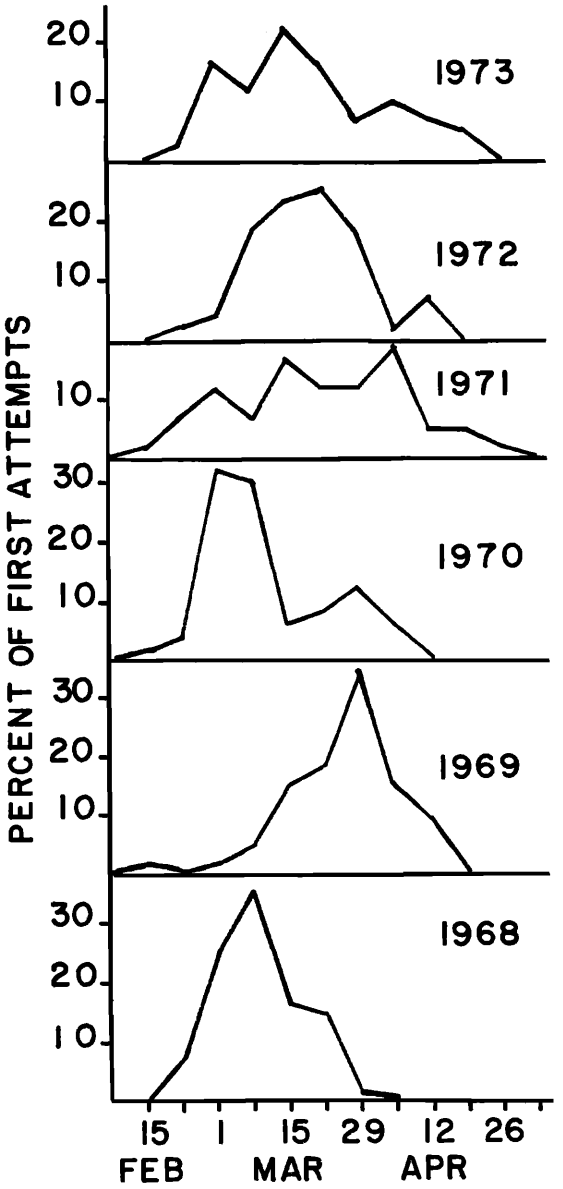

Figure 1. Percent of Great Blue Heron clutches of first nesting attempts started per week, 1968-1973, at Audubon Canyon Ranch.

until 25 March after most clutches had been started. Cold weather in March of 1969 may have delayed laying early in the month (Pratt 1972b) but 34% of the clutches were started in one week in that year and about the same percentage were started in one week in 1968 and 1970. In 1971-1973 clutch initiation was slower. Not more than 25% of the clutches were started in one week and in 1971 the maximum was only 17%. March was relatively cold in 1971 and 1973. Mean temperatures for March taken at the Point Reyes Bird Observatory were 45.9°F in 1971, 47.9° in 1972, and 42.6° in 1973. I previously explained the lag in laying in 1971 as the result of cold weather (Pratt 1972b), but low temperatures alone seem insufficient to explain the very slow rate of clutch initiation in that year since 1973 was even colder and the lag in 1973 was less pronounced.

Ability of females to find enough food to form eggs may also influence the dates of laying (Lack 1966:272-273, Perrins 1970), laying being delayed until the food supply is adequate for egg formation. The slower rates of clutch initiation in 1971-1973 may thus indicate that food was harder to find during laying in those years than in 1968-1970.

The years 1971-1973 were also characterized by smaller Great Blue Heron clutch size (Table 3). The mean of 3.2 for the years 1971-1973 was significantly lower than the mean of 3.6 for 1967-1970 ($p<.01$). The mean of 3.6 is in close agreement with the mean of 3.66 reported by Henny (1972) for Great Blue Herons in central California.

In some species of birds where breeding is delayed past the first year, females breeding for the first time lay later and lay smaller clutches than experienced birds (Coulson and White 1958, Fisher 1969, Richdale 1957, Woolfenden 1973). This could be true for herons also although I know of no studies substantiating it. It seems unlikely, however, that the proportion of females breeding for the first time would increase enough to account for the observed difference in clutch size and laying dates for three consecutive years.

Clutches laid late, independent of the age of females, have been shown to be smaller for the Black-legged Kittiwake (*Rissa tridactyla*) than those laid early (Coulson and White 1961). However heron clutches were not reduced in 1961 when laying was late.

The amount of food available to the female when the eggs are being formed may affect clutch size. When food is hard to find, clutches may be smaller than when it is easily obtained (Lack 1966:6). Thus the reduction in heron clutch size in 1971-1973 coinciding with the lag in laying supports the hypothesis that laying females may have had difficulty finding food early in those seasons.

The number fledged per successful nest did not decline in the years when laying was later and clutch size was smaller (Table 1). Perhaps food became easier to find as the season progressed. In addition, a drop

in clutch size of the magnitude that occurred acting alone would have little effect on fledging success since the most frequent number fledged per successful nest was 2. Almost all the fourth chicks to hatch and many of the third chicks died, presumably of starvation, during the first weeks of their lives.

Mean Great Egret clutch size for 1971-1973 was also smaller than for the first four years (Table 4), although the difference between the mean of 3.0 for 1971-1973 and 3.2 for 1967-1970 was not statistically significant. The egrets start laying about a month after the herons when most heron clutches are complete. Thus if food became easier to find later in the season, egret clutch size might not be affected as much. The preferred prey of the egrets may differ from that of the herons by size or species as well, and its availability would not necessarily fluctuate in parallel with that of the herons.

Egret clutch initiation was not slowed in 1972 and 1973 (Figure 2). Most clutches were started in the week ending 5 April, the same week that laying peaked in 1969 and 1970 (Pratt 1972a). But in 1971 clutch initiation almost ceased between 19 April and 3 May. During this time 16 nests were started and abandoned before any eggs were laid, an unusually large number of nesting attempts to be terminated during building. The weather during these two weeks did not show disturbance

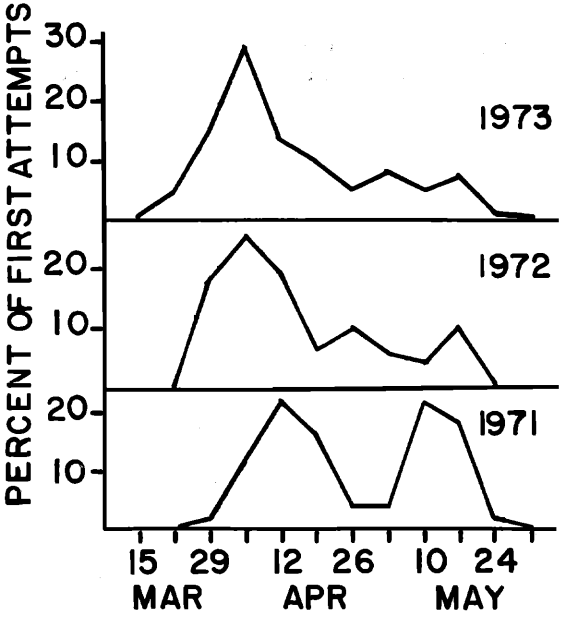

Figure 2. Percent of Great Egret clutches of first nesting attempts started per week, 1971-1973, at Audubon Canyon Ranch.

great enough to account for such a drastic decline in laying. Egret nests containing eggs did not show unusual disruptions at this time. Perhaps laying egrets experienced temporary difficulty in finding food necessary for egg formation but pairs with completed clutches were able to find enough food to sustain them during spells of incubation.

SUMMARY

Great Blue Herons at Audubon Canyon Ranch produced 1.7 young per breeding pair in 1972 and 1.5 in 1973. Egg loss declined in 1972 from the seven year high reached in 1971. Nestling loss was higher in 1973 perhaps because of disease or infestation of parasites. Breeding pairs increased from 46 in 1972 to 58 in 1973 coincident with desertion of two other small heronries within 28 km of Audubon Canyon Ranch.

Great Egret reproductive success increased to 1.5 young per breeding pair in 1972 from about 1.0 in the previous 4 years because of a decline in nesting attempts losing eggs. The decline in egg loss suggested partial recovery from DDT induced eggshell thinning. Egret production declined in 1973 to 1.2 fledglings per breeding pair due to increased nestling loss. The number of breeding pairs of egrets at Audubon Canyon Ranch increased to about 95 in 1972 and 1973 from about 85 in 1971.

Clutch size for the Great Blue Herons was significantly smaller in 1971-1973 than it was in 1967-1970 and laying was later. It is suggested that both occurred because the females may have had difficulty finding food during laying.

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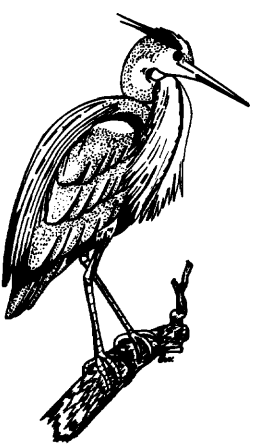

Sketch by Erv Deis