OOLOGICAL DATA ON EGG AND BREEDING CHARACTERISTICS OF BROWN PELICANS

DANIEL W. ANDERSON AND JOSEPH J. HICKEY

THE Gulf Coast population of the Brown Pelican (*Pelecanus occidentalis*) is now considered to be endangered by the AOU Committee on Conservation (1968). The circumstances surrounding its decline are not clear. Murphy (1936:102, 808–822) suggested that some breeding populations of Brown Pelicans "normally" fluctuate in response to fluctuating food supplies in relation to such factors as Humboldt Current changes, as well as other factors. Conney (1967), Kupfer (1967), Peakall (1967), Risebrough et al. (1968), and Wurster (1969) have explained some potential physiological effects of chlorinated-hydrocarbon and related environmental pollutants on mammalian and avian reproduction, which might apply, as well.

This paper presents information, obtained from major oological collections in North America, regarding some egg and reproductive parameters of the Brown Pelican. Ratcliffe (1967) and Hickey and Anderson (1968) have utilized oological sources to document changes in shell thickness and shell weight among seven species of birds. These changes were related to (1) the widespread introduction of persisting chlorinated hydrocarbons into the environment and (2) reproductive failures associated with shell-breakage and loss.

The lack of field data regarding certain breeding and egg characteristics from prior to and possibly during the decline of the Brown Pelican necessitated our attempt to glean whatever information possible from museum and private-egg collections. An understanding of the present situation, in addition, requires an evaluation of the geographical and temporal variations in the characters of interest.

METHODS

Measurements.—Eggs were weighed to the nearest 0.01 gram (g) on a torsion balance. Improper cleaning undoubtedly influences shell-weight and possibly also shell-thickness measurements. We used four criteria to determine if eggs had been properly blown: (1) a tendency to settle to one side when rolled on a smooth surface, (2) loose contents, (3) roughness on the interior of the shell, and (4) visual examination. In the course of measuring over 34,000 eggs of 25 species, we found about 200–300 broken or cracked eggs and a larger number with large holes. These lent themselves to close examination, and all proved to be satisfactorily cleaned. Eggs with holes larger than 7 mm were either not measured, or their weights were corrected to those with a 3-mm hole. This was accomplished by taking a small piece of shell, weighing it, and visually "filling" the hole. Egg lengths and breadths were measured to the nearest 0.01 centimeter with a standard, precision vernier caliper. Egg shapes were determined by comparison with the shapes

TABLE 1

CLUTCH SIZES AND INCUBATION STAGES OF EGGS TAKEN BY OOLOGISTS PRIOR TO 1943

Est. Stage of Incubation	Incubation Rating	Sample Size	Mean Clutch Size	95% C. L.
First egg–3 days[1]	1	72	2.94	0.32
4–12 days	2	137	2.93	0.31
13–21 days	3	27	3.07	0.50
22–30 days	4	0	—	—
All combined	—	236	2.95	0.27

[1] This stage represents a period of approximately 9 days.

described by Palmer (1962:13) and Preston (1968). Shell thickness was measured to the nearest 0.01 mm with a specially adapted micrometer, the procedure being described by Hickey and Anderson (1968). Thickness included shell and associated membranes at the girth of each egg.

Information from Data Slips.—Data slips, giving species, date of collection, stage of incubation, location, collector, and other pertinent information accompanied each set of eggs we measured. Due to the inadequacy of incubation terminology and the inability to identify incubation stage accurately (Storer, 1930), mean dates of set-collection (corrected on the basis of reported incubation to give date of clutch completion) can only provide an estimate of breeding phenology. The dates together for an area really only represent a mean over the years, but do suggest general trends and provide an index to length and variability of breeding season from region to region. We felt that oologists' estimates of incubation could, at best, only be categorized to the nearest one-fourth of the period from first egg to the end of incubation. The incubation period of the Brown Pelican is not precisely known (Palmer, 1962:277). We have used Mason's (1945) estimate of about 30 days for our calculations here and have estimated the mean number of days that our samples were incubated on the basis of our four incubation categories (Table 1, col. 1). In our series of samples, mean stage of incubation in days subtracted from mean date of set-collection provided an estimate of date of clutch completion. Unincubated ("fresh") eggs were included in the analysis of clutch size, after testing to determine if fresh sets might be biased by the collection of incomplete clutches. When sets of fresh eggs were separately compared with those of later incubation (t-test), no significant differences in clutch size were found ($P > 0.05$, Table 1). There remains the possibility that some egg collectors sought larger clutches.

Calculations and Indices.—All data were analyzed with an IBM 1620 computer. Statistical analyses followed Steel and Torrie (1960). A size index for eggs was calculated by multiplying length by breadth and was used as a crude index to volume. In a study of White Pelicans (*P. erythrorhynchos*) (D. W. Anderson and J. J. Hickey, unpublished), we have found displaced volume to be correlated with this size index ($P < 0.001$).

Geographical variations in egg size, shell thickness, shell weight, clutch size, and egg dates were determined in a stepwise manner as follows: (1) current subspecific range boundaries were determined from the AOU Check-list (1957) and Palmer (1962:275), and the range was then subdivided into small geographic units such as a single state; (2) the eggshell data for these were then tested for significant differences and regrouped until a region was obtained containing a maximum number of subunits that were not significantly different from each other; (3) groupings never included more than one

TABLE 2

GEOGRAPHICAL VARIATION IN EGGSHELLS OF NORTH AMERICAN BROWN PELICANS, 1879 TO 1943[1]

Subspecies Area	occ West Indies	car S.C.	car Fla., Ga.	car La.	car Panama	car Texas	cal Baja Calif.	cal So. Calif.
Number	6	43	208	42	7	115	174	85
Wt. (g)	8.05	9.46	9.78	9.87	9.94	10.00	10.99	10.59
±95% C.L.	±0.90	±0.35	±0.12	±0.32	±0.49	±0.26	±0.18	±0.24
Size Index (cm^2)	33.2	37.6	37.6	38.2	37.4	38.5	40.0	39.0
±95% C.L.	±0.6	±0.9	±0.3	±0.7	±1.0	±0.6	±0.4	±0.7
No. Subelliptical	3	21	109	20	2	52	94	44
No. Oval	3	22	99	22	5	63	80	41
Thickness Index[2]	2.42	2.52	2.60	2.58	2.66	2.59	2.74	2.71
±95% C.L.	±0.24	±0.06	±0.02	±0.06	±0.10	±0.04	±0.02	±0.04
Number	6	23	172	24	—	43	83	28
Thickness (mm)	0.510	0.557	0.557	0.554	—	0.557	0.569	0.579
±95% C.L.	±0.031	±0.021	±0.004	±0.014	—	±0.012	±0.008	±0.014

[1] The pre-1943 means that were not significantly different at the 95% level in Duncan's New Multiple Range Test (Steel and Torrie, 1960:107–109, 114) are underscored.
[2] From Ratcliffe (1967): Thickness index = 10 × wt. in g/(length × breadth in cm).

described subspecies; and (4) phenological subdivisions were kept at the smaller units without regrouping.

RESULTS AND DISCUSSION

Geographical Variation in Egg Parameters.—Egg-size index, shell weight, and shell thickness (Table 2) tended to vary with the size of the bird as discussed by Romanoff and Romanoff (1949:150). Our index to body size was obtained by using two common standard measurements that tend to measure skeletal size (tarsus and culmen) (Fig. 1). These skeletal measurements were taken from Wetmore (1945) and represent those of female birds. Wetmore (1945) ranked the size of the three North American subspecies, from largest to smallest as follows: *P. o. californicus*, *P. o. carolinensis*, and *P. o. occidentalis*.

The general shape categories (Table 2) were, nonetheless, not significantly different ($P > 0.05$, Chi-square test) from area to area or between subspecies. Ordinary shape changes in the eggs of domestic poultry have already been shown to have little effect on the shell present as a percentage of total egg weight (Asmundson and Baker, 1940).

Of the subspecies *carolinensis*, birds from Texas tended to have the largest

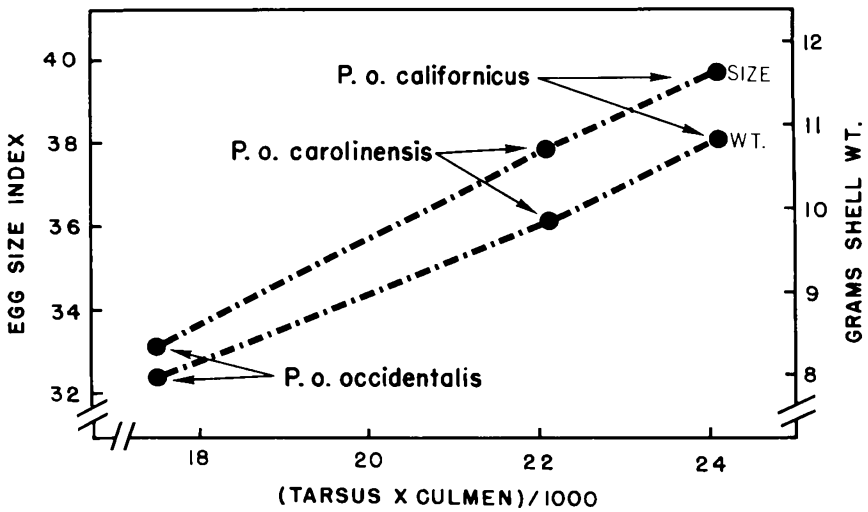

FIG. 1. Relationship between two egg measurements and index to body size in three subspecies of Brown Pelicans. The index to body size was calculated in mm^2 units and is shown on the abscissa. Eggshell size was taken as the product of length and breadth in cm^2.

eggs. Louisiana eggs tended to be intermediate between those from Texas and those from areas to the east (Table 2). South Carolina birds tended to have smaller and lighter-shelled eggs than birds from farther south in Florida and Georgia, although not significantly so (Table 2). The Baja California eggs (*P. o. californicus*) were represented mostly by specimens from Los Coronados Island but suggested a similar gradient, with egg size decreasing from southern to northern colonies. Lack (1968:279) mentioned this trend among certain congenerics in certain tropical Procellariiformes. A continuum in egg size and shell weight between different populations from different areas was suggested in our specimens, especially in *carolinensis*, although shell thickness in the various subspecies seemed relatively stable. Whether or not the intrasubspecific tendencies are genetic is unknown. They are likely genetic, but standard measurements from museum skins are needed for further comparisons. The intersubspecific variations in egg size are most likely representative of body size (Fig. 1).

If one assumes that egg size provides an index to body size, the large Texas birds may represent an intermediate between *californicus* and *carolinensis*. Brown Pelicans along the Pacific Coast (*californicus*) have the larger and thicker-shelled eggs (Table 2). Asmundson et al. (1943) showed that larger eggs in several species tended to have the thicker shells, but the essentially

equal thicknesses from all our Gulf and Atlantic Coast eggs suggested that this relationship was not present on an intrasubspecific basis. The small sample of eggs from Panama suggested that these eggs were most similar to the subspecies *carolinensis*, as Wetmore (1945) has shown with museum skins. Unfortunately, we were unable to obtain egg measurements from Ecuadorian or Peruvian Brown Pelicans. Murphy (1936:820) reported that the Peruvian pelicans are very large and we suspect that their eggs would also be larger and thicker-shelled.

The ecological significance of egg-size difference within a species is largely a matter of speculation. Lack (1966:7) suggests that egg-size differences between different species (and larger groups) are mainly a matter of heredity. The differences we observed on an intersubspecific basis in Brown Pelicans at least implied that these eggs are represented by relatively distinct gene-pools. Perhaps such gene-pools are even distinct on an intrasubspecific basis. Mason (1945) showed that Florida Brown Pelican movements, at least, are somewhat restricted under normal circumstances, suggesting potential isolation between breeding groups. Welty (1962:408 quoting Murphy, 1936) also suggests that this species is potentially sensitive to isolating barriers.

Possible Factors for Bias.—It is not our primary objective here to speculate on taxonomic relationships on the basis of eggs; nonetheless, the variations in eggs are expected to relate in some ways to taxonomic characters (Tyler, 1964, 1965). Our interest is mainly to examine natural variation in order to better understand if unnatural change has occurred.

Egg size and shell thickness and composition are known to vary with heredity, age, adult physiological condition, diet, and chemical influence (Romanoff and Romanoff, 1949:152–157, 359; Preston, 1958; Sturkie, 1965: 464, 487–488; Simkiss, 1967:157–197). Shell thickness also varies in different areas of the egg of a given species, the most notable examples probably being the rock-nesting murres (*Uria* sp.) and other seabirds, where thickness tends to increase at the most vulnerable parts (Tuck, 1960:25). Some interspecific differences in thickness have been shown to be related to the hazards associated with placement on different nesting substrates (Belopol'skii, 1957: 133–134). Fortunately, egg collectors drilled their specimens at the girths, the most uniform area for most species (Romanoff and Romanoff, 1949: 157–158).

Shell calcium (about 5 per cent) is utilized, as well, by developing embryos (Simkiss, 1967:198–213); hence, shell weight and also possibly thickness may be biased low if eggs of late-stage incubation are used in the shell-thickness or weight comparisons. Data combined into *carolinensis* and *californicus* categories indicated this trend (Table 3), although not significant statistically (t-test, $P > 0.05$) and only amounting to a small percentage

TABLE 3

SHELL WEIGHTS OF PRE-1943 EGGS OF TWO SUBSPECIES OF BROWN PELICAN AT DIFFERENT INCUBATION STAGES

Subspecies Incubation Stage	No.	Mean Wt. (g)	95% C.L.
carolinensis			
First egg–3 days	98	9.75	0.21
4–12 days	230	9.88	0.14
13–21 days	53	9.76	0.28
californicus			
First egg–3 days	92	10.75	0.20
4–12 days	121	10.97	0.25
13–21 days	30	10.59	0.40
Both			
First egg–3 days	190	10.23	0.16
4–12 days	351	10.26	0.14
13–21 days	83	10.06	0.24

in our sample (1–3 per cent). Therefore, we do not believe this bias to be important in the oological data examined here. Furthermore, the data suggested that most egg collectors tended to collect eggs that were about one-third or less incubated (Table 1), thus eggs in late-stage incubation represented a small percentage of our sample. Although effects on the egg stemming from the age and physiology of the laying female would remain undetectable in oological samples, they would not be expected to affect an overall random, or essentially random, sample (see Asmundson et al., 1943).

Eggshell Changes and Pesticide Residues.—The small samples of post-1949 specimens suggested thinning in all eggshells measured (Table 4). Florida specimens showed a –17 per cent change in shell weight, Texas specimens a –20 per cent change, California specimens (Anacapa Is.) a –26 per cent change, and one set of eggs from Panama a –15 per cent change. All were significant ($P < 0.05$) changes. We could detect no change in shape in these post-1949 eggs ($P > 0.05$, Chi-square test). The incubation stages were essentially the same for both pre-1943 and post-1949 eggs (6 ± 2 days *vs.* 9 ± 5 days, 95 per cent C.L.). Size indices were not significantly different ($P > 0.05$), although the post-1949 eggs from Texas and Florida were slightly smaller in mean than those of pre-1943. Whether or not these changes in weight and thickness were associated with either recent declines of the Brown Pelican or environmental pollution, or both, remains to be determined.

Stickel (1968) has stated that in Gulf Coast Brown Pelicans, pesticide residues were of approximately the same general magnitude as those of herons

TABLE 4

POST-1949 EGGSHELL MEASUREMENTS OF BROWN PELICANS[1]

Subspecies Area	*carolinensis* Florida	*carolinensis* Texas	*carolinensis* Panama	*californicus* California
Number	9	6	3	9
Wt. (g)	8.10	7.96	8.45	7.89
±95% C.L.	±0.14	±0.60	±0.99	±0.66
Size Index (cm^2)	36.5	37.6	37.6	39.0
±95% C.L.	±0.9	±2.4	±2.0	±1.4
No. Subelliptical	1	2	2	7
No. Oval	8	4	1	2
Thickness Index[2]	2.22	2.12	2.25	2.02
±95% C.L.	±0.09	±0.10	±0.22	±0.12
Number	—	—	3	9
Thickness (mm)	—	—	0.457	0.424
±95% C.L.	—	—	±0.012	±0.018

[1] Post-'49 eggs were collected as follows: Florida—1950, 1953; Texas—1951; Panama—1952; California—1962.

[2] From Ratcliffe (1967): Thickness index = 10 × wt. in g/(length × breadth in cm).

(*Ardea cinerea*) from Great Britain and Bald Eagles (*Haliaeetus leucocephalus*) in the United States (see Stickel et al., 1966; and Moore and Walker, 1964). Risebrough et al. (1967) analyzing two Brown Pelican eggs from the Gulf of California found them to be generally "low" in pesticide content (0.7 ppm [wet-weight basis] DDT and metabolites and about one-fifth as much polychlorinated biphenyls [PCB's], an industrial pollutant; endrin and dieldrin were also identified). They found an average of 0.8 ppm DDT-family residues (61 per cent DDE) and about two-thirds as much PCB in six Brown Pelican eggs taken in Panama. We converted the above residues to a ppm wet-weight basis by assuming 7 per cent fat in the eggs. We measured two of the eggshells from Risebrough's study (Baja California specimens) and found one suggestive of a "normal" egg (11.7 g, 0.59 mm in thickness) and the other suggestive of thinning (9.3 g, 0.50 mm). Another study (Anderson et al., 1969) showed that egg residues as low as 1 ppm of DDE, and possibly less, could be associated ($P < 0.05$) with detectable shell changes in White Pelicans, although egg residues may not always necessarily reflect residues in adults that could influence egg-shell deposition. Risebrough et al. (1967) reported 84.4 ppm of DDT-type residues, 91 per cent of which was *p,p'*-DDE (77 ppm) in the breast muscle of a Brown Pelican collected in California. These levels are only slightly lower than those reported from Lake Michigan Herring Gulls (*Larus argentatus*), which averaged 80 ppm DDE in the breast of adult birds (Hickey et al., 1966). Reproduction in the

TABLE 5
MEAN DATES OF CLUTCH COMPLETION IN BROWN PELICANS FROM VARIOUS GEOGRAPHICAL AREAS

Area	No. Clutches	Mean Date ± S.D.	Mean Stage Incubation[1]
So. California	29	8 April ± 16 days	1.4
No. Baja California	61	10 April ± 54 days	1.8
Texas	36	9 May ± 18 days	1.5
Louisiana	14	27 April ± 31 days	1.6
Florida	75	29 May ± 125 days	1.9
South Carolina	14	5 June ± 17 days	1.7

[1] Numerically coded with Table 1, cols. 1–2.

Wisconsin Herring Gull population in Green Bay (characterized by egg-breakage) is known to be severely affected by DDE and other residues (Keith, 1966; and Hickey and Anderson, 1968). Egg residues from the same population averaged 183 ppm DDE in 1963 and 1964 (Keith, 1966).

Breeding Characteristics.—Pacific Coast data suggested that between northern Baja California and California, the breeding dates were somewhat closely related (Table 5). Gulf and Atlantic Coast birds, on the other hand, showed much variation, especially in Florida (Appendix 1) as discussed by Bent (1922:295) and Palmer (1962:277). Palmer's (1962:275) distribution map suggests that on the Pacific Coast, the major breeding populations of *californicus* are concentrated into a smaller area than those from Gulf and Atlantic Coast sites (*carolinensis*). Bent (1922:296), Howell (1932:85–87), and Lowery (1960:113–114) noted that Brown Pelicans of the subspecies *carolinensis* tended to utilize trees as well as coastal beaches and islands as nesting substrates. Murphy (1936:810–814) mentioned diverse breeding sites for South American pelicans as well. The Brown Pelicans of northern Baja California and California seem more generally restricted to ground-nesting on islands (Bent 1922:301; Williams, 1927). Bond (1942) reported tree-nesting for the California Brown Pelican as very unusual.

In Florida, where the Brown Pelican still persists (Williams and Martin, 1969), a long breeding season and diversity of nesting substrate seem to characterize breeding. They nest year-round in Peru, although considerable shifting of sites occurs (Murphy, 1936:821–822). The Gulf of California Brown Pelicans still persist as breeders, although there is no evidence of a longer breeding season than in colonies farther north (R. W. Risebrough, pers. comm.).

Clutch sizes showed no significant variation ($P > 0.05$) between any of the geographical areas listed in Table 2. The means, and our best estimates for clutch-size in the Brown Pelican, are given in Table 1. Bent (1922:297)

and Palmer (1962:277) stated that three eggs, and less often two, is the normal clutch size; nests with four and five eggs have been found.

Breeding Records.—The population estimates by egg collectors cited in Appendix 1 must be viewed cautiously. These estimates were subject to observer error; however, they can provide an approximation of changes that might have occurred. Data-slip information, although most likely sketchy, can also provide documentation of past breeding locations. The records we found in egg collections did not provide a complete picture of breeding localities but suggested possible fluctuations in numbers over the years (Appendix 1). On the other hand, none of the major colonies seem to have been completely without birds since at least the late 1800's. Numbers probably increased on Anacapa Island, California, during the late 1920's. Williams (1927) reported a colony as far north as Point Lobos, California, during this time. The late 1920's may represent a period of population increase. Bond (1942) reported the estimated numbers on Anacapa Island from 1898 to 1941 to be highly fluctuating (estimates ran from about 200 to at least 2000 pairs). Banks (1966) reported eggs and young on Anacapa and essentially "normal" numbers of breeding birds, at least in 1963 and 1964, two years after the thin-shelled eggs reported here. The Los Coronados birds seem historically more stable (Appendix 1). It is certain that both Anacapa and Los Coronados breeders were historically present in large numbers (Banks, 1966). Risebrough (1968) and Schreiber and DeLong (1969) suggested that the Brown Pelican has decreased considerably in recent years off California, including no known breeders on Los Coronados in 1968. Perhaps the –20 to –26 per cent figure in shell change represents or approaches the lower limit to which eggs may survive to be collected by egg-collectors. Certainly, some production occurred in the California colony with these shell-changes, although present numbers suggest a declining population. Lowery (1960:113–114) mentions large colonies in Louisiana; yet Winckler (1968), in a popular article, summarized their nearly virtual disappearance from the Gulf Coast by 1968. In the light of the better-known demise of Gulf Coast Brown Pelicans, we believe the status of California Brown Pelicans and populations farther to the south needs immediate study.

SUMMARY

Mean clutch size in 236 sets of North American Brown Pelican eggs was 2.95 and did not vary geographically between North American populations. Shell weight varied from 8.05 g to 10.99 g along a geographic continuum. Shell thickness averaged 0.510 mm for *Pelecanus occidentalis occidentalis*, 0.554–0.557 mm for *P. o. carolinensis*, and 0.569–0.579 mm for *P. o. californicus*. The ranges of breeding dates for the more southern populations were wider than those of northern ones.

Small numbers of eggs taken in Texas and Florida after 1949 were 20 per cent below normal weight; 1962 eggs from California were 26 per cent below normal; and three

taken in Panama, 15 per cent below normal. Shell thickness had likewise decreased 15–27 per cent.

ACKNOWLEDGMENTS

This study was carried out as part of a contract with the Bureau of Sport Fisheries and Wildlife, Fish and Wildlife Service, U.S. Department of the Interior, Patuxent Wildlife Research Center, Laurel, Maryland.

We are grateful to the many curators of museum collections listed in Appendix 1. The private collectors cited in Appendix 1 were extremely cooperative. We are especially grateful to Ed N. Harrison and Wilson C. Hanna for their personal assistance and extremely helpful suggestions. Mr. Harrison, in addition, located our 1962 samples of California eggs. Lucille F. Stickel and Eugene H. Dustman provided critical advice, and Ralph W. Schreiber suggested the immediate consolidation of our Brown Pelican data. Mrs. Pearl Davis punched our data cards, and the College of Agricultural and Life Sciences, University of Wisconsin, provided computer facilities at no cost. We are grateful to J. O. Keith and R. W. Risebrough for critical advice on the manuscript.

APPENDIX 1

BROWN PELICAN BREEDING RECORDS TAKEN FROM NORTH AMERICAN OOLOGICAL RECORDS AND COLLECTIONS.

Date	Location	Estimated Numbers; Remarks	Observer	Museum* of record
Southern California				
27 May 1893	Anacapa Is.	—	A. H. Miller	2
5 June 1910	Anacapa Is.	500+ pairs	G. Willett	3,5
7 Mar. 1916	Anacapa Is.	—	M. C. Badger	2
2 Mar. 1917	Anacapa Is.	—	M. C. Badger	3
15 May 1919	Anacapa Is.	—	—	1
7 Mar. 1920	Anacapa Is.	5,000+ pairs	S. B. Peyton	30
8 Mar. 1922	Anacapa Is.	—	S. B. Peyton	5
28 Mar. 1927	Anacapa Is.	—	—	3
24 Feb. 1929	Anacapa Is.	—	C. W. Ashworth	2
1 Mar. 1936	Anacapa Is.	—	E. Harrison	3
1 Mar. 1936	Anacapa Is.	2,000+ pairs	L. T. Stevens	14
12 Mar. 1939	Anacapa Is.	"large colony"	L. T. Stevens	4,7
19 May 1919	San Miguel Is.	—	—	1
25 May 1927	Point Lobos	8–10 nests	L. Williams (1927)	2
Baja California, Mexico				
18 Apr. 1894	Los Coronados	—	E. Parker	27
19 Apr. 1894	Los Coronados	—	—	1
4 Apr. 1895	Los Coronados	—	A. Hewitt	2,22
19 Apr. 1898	Los Coronados	—	A. J. Kellog	24
27 Apr. 1898	Los Coronados	—	—	3
6 May 1904	Los Coronados	—	O. C. Polling	2
6 Apr. 1908	Los Coronados	500 nests	P. I. Osborne	1,4

(APPENDIX 1 CONTINUED)

Date	Location	Estimated Numbers; Remarks	Observer	Museum* of record
6 Apr. 1908	Los Coronados	—	A. Van Rossem	25
1 July 1908	Los Coronados	—	P. I. Osborne	9
4 Apr. 1910	Los Coronados	—	P. I. Osborne	29
2 Apr. 1912	Los Coronados	—	C. S. Thompson	23
1 Apr. 1913	Los Coronados	500 nests	L. M. Huey	3
29 Mar. 1914	Los Coronados	—	W. C. Bradbury	2,9
31 May 1915	Los Coronados	—	I. D. Nokes	5
26 Mar. 1917	Los Coronados	500 pairs	N. K. Carpenter	6
4 May 1917	Los Coronados	—	D. S. DeGroot	2
11 Apr. 1919	Los Coronados	—	N. K. Carpenter	23
12 May 1921	Los Coronados	—	W. C. Hanna	4
30 Mar. 1922	Los Coronados	—	—	1
15 Apr. 1881	Mexican coast	—	—	1
26 Mar. 1917	So. Coronados, SE slope	—	—	1
6 Apr. 1920	Todos Santos Is.	—	G. Bancroft	4
6 Apr. 1920	Todos Santos Is.	—	J. Burnham	26
17 Apr. 1921	San Pedro Nolasco Is.	—	—	1
2 May 1921	Granite Is.	—	—	1
7 Apr. 1932	San Benito Is.	—	E. Harrison	3
10 Apr. 1932	San Martín Is.	—	E. Harrison	3
2 June 1932	Asunción Is.	—	E. Harrison	3
Panama				
15 Feb. 1942	Chama Is., Panama Bay, Panama	—	A. Wetmore	13
15 Mar. 1952	Taboga Is., Panama	—	A. Wetmore	13
Texas				
10 May 1886	Near Corpus Christi	—	F. B. Armstrong	12
20 May 1888	Neuces Co.	—	T. S. Gillin	4
10 Apr. 1889	So. Bird Is., Laguna Madre	—	J. A. Singley	2
16 Apr. 1889	So. Bird Is., Laguna Madre	—	J. A. Singley	4,25
14 June 1894	25 mi. from Corpus Christi	—	F. B. Armstrong	1
14 May 1896	So. Bird Is., Laguna Madre	—	D. B. Burrows	2
28 May 1910	Near Corpus Christi	—	C. E. Farley	30
30 May 1910	Near Corpus Christi	—	J. M. Carroll	4
3 May 1912	Laguna Madre	—	J. M. Priour	4
18 May 1913	Neuces Co.	—	F. B. Armstrong	9
27 May 1915	Padre Is.	—	F. B. Armstrong	2
19 May 1917	Big Bird Is., Laguna Madre	—	R. W. Quillan	19

(APPENDIX 1 CONTINUED)

Date	Location	Estimated Numbers; Remarks	Observer	Museum* of record
May 1919	Is. off so. coast	—	—	3
15 May 1919	Laguna Madre	—	H. Brandt	10
5 May 1922	Neuces Co.	—	G. Stewart	11
24 May 1925	Pelican Is., Aransas Bay	—	R. D. Camp	31
1951	Refugio Co.	—	T. C. Meitzen	18
Louisiana				
29 Mar. 1893	Lost Is.	—	F. A. McIlhenny	2
28 Mar. 1894	Marsh Is.	—	F. A. McIlhenny	2
29 Mar. 1894	Shell Keys	—	F. A. McIlhenny	2,23
3 June 1919	Pass à l'Outre	—	E. R. Kalmbach	13
5 June 1919	Errol Is.	—	J. D. Figgins	9
26 May 1938	North Is.	—	F. Tobin	10
13 Apr. 1940	La Fourche Par., Timbalier	—	G. H. Lowery (1960)	17
Florida				
15 Mar. 1879	Near Marco	—	—	1
1 Apr. 1880	Indian R.	—	C. L. Gass	26
15 Apr. 1880	Indian R.	—	—	1
29 Apr. 1880	Old Tampa Bay	—	—	1
12 Apr. 1890	Lee Co.	—	H. R. Jamison	4
12 Apr. 1890	Charlotte Harbor	—	S. Reiff	21
3 May 1890	W. of Pine Is., Lee Co	225 nests	N. K. Jamison	4
26 Apr. 1891	Pelican Is.	—	M. Gibbs (1894)	9
12 Apr. 1892	Tampa Bay	—	D. P. Ingraham	27
10 May 1893	Pelican Is.	—	J. M. Southwick	4
5 June 1893	Mullett Key	—	B. T. Smith	26
30 June 1894	Tampa Bay	—	—	1
21 Jan. 1896	Pelican Is.	500 pairs	B. W. Evermann	23
3 Apr. 1896	Pelican Is.	—	H. E. Pendry	3
30 Apr. 1896	Seminole Is.	—	H. E. Pendry	5
18 May 1896	Rookery Is., off Diston City	—	W. Meyor	8
15 May 1899	Brevard Co.	—	F. S. Webster	10
19 Apr. 1908	Boca Grande, Charlotte Keys	200 birds	P. B. Phillipp	12
20 Apr. 1908	Charlotte Harbor, Devilfish Key	—	P. B. Phillipp	12
3 May 1911	Pelican Is.	—	P. B. Phillipp	12
19 May 1911	Hillsborough Co.	—	O. E. Baynard	24
27 Apr. 1913	Lee Co.	—	O. E. Baynard	3,9
27 Apr. 1913	Roco Bay, Pinellas Co.	large colony in trees	O. E. Baynard	8

(APPENDIX 1 CONTINUED)

Date	Location	Estimated Numbers; Remarks	Observer	Museum* of record
15 May 1918	Tampa Bay	—	J. L. Vaughn	4
20 Apr. 1920	Tampa Bay	—	—	3
17 May 1921	Tampa Bay	—	J. L. Vaughn	2,20
17 May 1921	Tampa Bay	—	W. F. Lewis	8
27 May 1921	Tampa Bay	—	J. L. Vaughn	23
28 Dec. 1921	Pelican Is.	—	T. D. Burleigh	10
20 Apr. 1926	Pinellas Co.	—	C. E. Doe	16
1 June 1926	Merritt Is.	—	K. Squires	2
10 June 1929	Merritt Is.	2,500 pairs	J. C. Howell, Jr.	12
28 Mar. 1930	Lee Co.	—	C. E. Doe	16
25 Apr. 1930	Near Bokelia?	—	C. E. Doe	16
10 Apr. 1931	Mosquito Lagoon, Brevard Co.	2,000± nests	W. H. Nicholson	23
6 June 1931	Pine Is. Res., Bird Key	—	R. W. Williams	13
7 June 1931	Matlacha Pass Res., 6-mi. Is.	—	R. W. Williams	13
3 May 1932	Bird Key, Hillsborough Co.	—	R. E. Gammell	7
22 Apr. 1934	Rattlesnake Key, Levy Co.	—	C. E. Doe	16
9 Mar. 1950	Is., n. side of Cocoa—Cocoa Beach	375 nests	C. E. Carter	15
10 Mar. 1953	Merritt Is.	—	H. Brandt	10
Georgia				
16 June 1898	Chatham Co.	on beach	T. D. Perry	1,16
South Carolina				
10 May 1901	Bird Bank, Bull's Bay	—	M. T. Cleckley	9
20 June 1901	Near Charleston	on beach	—	3
23 June 1901	Bay Point, near Beaufort	"large colony"	M. T. Cleckley	3
23 May 1915	Bird Bank, Bull's Bay	—	A. C. Bent	13
18 June 1915	Bird Bank, Bull's Bay	—	A. Sprunt, Jr.	30
7 July 1916	Bull's Bay	—	M. T. Cleckley	28
3 June 1925	Bull's Bay	—	W. B. Savary	5
14 June 1934	Georgetown Co.	—	H. L. Harllee	14
20 June 1942	Bull's Bay	—	E. J. DeCamps	14
10 June 1943	St. Helens Sound, Beaufort (Bird Bank)	—	E. J. DeCamps	4
10 July 1943	18 mi. e. Beaufort	—	E. J. DeCamps	14
Cuba				
8 Sep. 1930	Cacachita Bay	—	P. Bartsch	13

* Museums and collections are numbered as follows: 1. Calif. Acad. Sci., San Francisco; 2. Mus. Vert. Zool., Univ. Calif., Berkeley; 3. Western Found. Vert. Zool., Los Angeles, Calif.; 4. San Bernardino Co. Mus., San Bernardino, Calif.; 5. S. B. Peyton, private collection, Fillmore, Calif.; 6. Oakland Publ. Mus., Oakland, Calif.; 7. Santa Barbara Mus. Nat. Hist., Santa Barbara,

Calif.; 8. San Diego Mus. Nat. Hist., San Diego, Calif.; 9. Denver Mus. Nat. Hist., Denver, Colo.; 10. Carnegie Mus., Pittsburgh, Pa.; 11. Philadelphia Acad. Sci., Philadelphia, Pa.; 12. Amer. Mus. Nat. Hist., New York, N.Y.; 13. U.S. Natl. Mus., Wash., D.C.; 14. Zoological Mus., Clemson Univ., Clemson, S.C.; 15. C. E. Carter, private collection, Orlando, Fla.; 16. Fla. State Mus., Gainesville; 17. L.S.U. Mus. Nat. Sci., Baton Rouge, La.; 18. T. C. Meitzen, private collection, Refugio, Tex.; 19. R. W. Quillan, private collection, San Antonio, Tex.; 20. Univ. Kans. Mus. Nat. Hist., Lawrence; 21. Univ. Nebr. Zool. Dept. Mus., Lincoln; 22. Cleveland Nat. Sci. Mus., Cleveland, Ohio; 23. Royal Ont. Mus., Toronto; 24. Joseph Moore Mus., Earlham Coll., Richmond, Ind.; 25. Ohio State Mus., Ohio State Univ., Columbus; 26. Univ. Mich. Mus. Zool., Ann Arbor; 27. James Ford Bell Mus. Nat. Hist., Univ. Minn., Mpls.; 28. M. Pollock, private collection, Edmonton, Alta.; 29. Burke Memorial Mus., Univ. Wash., Seattle; 30. Puget Sound Mus. Nat. Hist., Univ. Puget Sound, Tacoma; 31. Zoology Mus., Ore. State Univ., Corvallis.

LITERATURE CITED

AMERICAN ORNITHOLOGISTS' UNION. 1957. Check-list of North American birds. Fifth ed.

AMERICAN ORNITHOLOGISTS' UNION. 1968. Report of committee on conservation, 1968. Auk, 85:669–677.

ANDERSON, D. W., J. J. HICKEY, R. W. RISEBROUGH, D. L. HUGHES, AND R. E. CHRISTENSEN. 1969. Significance of chlorinated hydrocarbon residues to breeding pelicans and cormorants. Canadian Field-Naturalist, 83:91–112.

ASMUNDSON, V. S., AND G. A. BAKER. 1940. Percentage shell as a function of shell thickness, egg volume and egg weight. Poultry Sci., 19:227–232.

ASMUNDSON, V. S., G. A. BAKER, AND J. T. EMLEN. 1943. Certain relations between the parts of birds' eggs. Auk, 60:34–44.

BANKS, R. C. 1966. Terrestrial vertebrates of Anacapa Island, California. Trans. San Diego Soc. Nat. Hist., 14:173–188.

BELOPOL'SKII, L. O. 1957. Ecology of sea colony birds of the Barents Sea. Israel Prog. for Scientific Translations, Jerusalem, 1961. Trans. by R. Ettinger and C. Salzmann.

BENT, A. C. 1922. Life histories of North American petrels and pelicans and their allies. U.S. Natl. Mus. Bull., 121.

BOND, R. M. 1942. Banding records of California Brown Pelicans. Condor, 44:116–121.

CONNEY, A. H. 1967. Pharmacological implications of microsomal enzyme induction. Pharmacol. Rev., 19:317–366.

GIBBS, M. 1894. Nesting habits of the Brown Pelican in Florida. Oölogist, 11:81–84.

HICKEY, J. J., J. A. KEITH, AND F. B. COON. 1966. An exploration of pesticides in a Lake Michigan ecosystem. J. Appl. Ecol., 3(Suppl.):141–154.

HICKEY, J. J., AND D. W. ANDERSON. 1968. Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. Science, 162:271–273.

HOWELL, A. H. 1932. Florida bird life. Coward-McCann, New York.

KEITH, J. A. 1966. Reproduction in a population of Herring Gulls (*Larus argentatus*) contaminated by DDT. J. Appl. Ecol., 3(Suppl.):57–70.

KUPFER, D. 1967. Effects of some pesticides and related compounds on steroid function and metabolism. Residue Reviews, 19:11–30.

LACK, D. 1966. Population studies of birds. Clarendon Press, Oxford.

LACK, D. 1968. Ecological adaptations for breeding in birds. Methuen, London.

LOWERY, G. H., JR. 1960. Louisiana birds. Louisiana State Univ. Press, Baton Rouge.

MASON, C. R. 1945. Pelican travels. Bird-Banding, 16:134–143.

MOORE, N. W., AND C. H. WALKER. 1964. Organic chlorine insecticide residues in wild birds. Nature, 201:1072–1073.

MURPHY, R. C. 1936. Oceanic birds of South America: Vol. I–II. Amer. Mus. Nat. Hist., New York.

PALMER, R. S. [Ed.] 1962. Handbook of North American birds: Vol. I. Yale Univ. Press, New Haven.

PEAKALL, D. B. 1967. Pesticide-induced enzyme breakdown of steroids in birds. Nature, 216:505–506.

PRESTON, F. W. 1958. Variation of egg size with age of parent. Auk, 75:476–477.

PRESTON, F. W. 1968. The shapes of birds' eggs: mathematical aspects. Auk, 85: 454–463.

RATCLIFFE, D. A. 1967. Decrease in eggshell weight in certain birds of prey. Nature, 215:208–210.

RISEBROUGH, R. W. 1968. Pollution, wildlife and science. Canadian Field-Naturalist, 82:241–243.

RISEBROUGH, R. W., D. B. MENZEL, D. J. MARTIN, JR., AND H. S. OLCOTT. 1967. DDT residues in Pacific sea birds: a persistent insecticide in marine food chains. Nature, 216:589–591.

RISEBROUGH, R. W., P. RIECHE [= REICHE], D. B. PEAKALL, S. G. HERMAN, AND M. N. KIRVEN. 1968. Polychlorinated biphenyls in the global ecosystem. Nature, 220: 1098–1102.

ROMANOFF, A. L., AND A. J. ROMANOFF. 1949. The avian egg. Wiley, New York.

SCHREIBER, R. W., AND R. L. DELONG. 1969. Brown Pelican status in California. Audubon Field Notes, 23:57–59.

SIMKISS, K. 1967. Calcium in reproductive physiology. Reinhold, New York.

STEEL, R. G. D., AND J. H. TORRIE. 1960. Principles and procedures of statistics. McGraw-Hill, New York.

STICKEL, L. F. 1968. Organochlorine pesticides in the environment. 2d Meeting on the Unintended Occurrence of Pesticides in the Environment, 19 Sept. 1967, Taymouth Castle, Scotland. Mimeo.

STICKEL, L. F., N. J. CHURA, P. A. STEWART, C. M. MENZIE, R. M. PROUTY, AND W. L. REICHEL. 1966. Bald Eagle pesticide relations. Trans. N. Amer. Wildl. and Nat. Resources Conf., 31:190–200.

STORER, T. I. 1930. A critique of oölogical data. Auk, 47:329–334.

STURKIE, P. D. 1965. Avian physiology. Comstock, Ithaca, New York.

TUCK, L. M. 1960. The murres. Canadian Wildl. Ser. 1, Canadian Wildl. Serv., Ottawa.

TYLER, C. 1964. Wilhelm von Nathusius, 1821–1899, on avian eggshells. Berkshire Printing Co., Reading.

TYLER, C. 1965. Egg-shell characteristics as a guide to taxonomy. Ibis, 107:131.

WELTY, J. C. 1962. The life of birds. W. B. Saunders, Philadelphia.

WETMORE, A. 1945. A review of the forms of the Brown Pelican. Auk, 62:577–586.

WILLIAMS, L. 1927. California Brown Pelicans nesting at Point Lobos, Monterey County, California. Condor, 29:246–249.

WILLIAMS, L. E., JR., AND L. MARTIN. 1969. Nesting status of the Brown Pelican in Florida in 1968. Quart. J. Florida Acad. Sci., 31:130–140.

WINCKLER, S. 1968. Brown Pelican epitaph. Texas Parks and Wildlife, 26(12):24–28.

WURSTER, C. F., JR. 1969. Chlorinated hydrocarbon insecticides and avian reproduction: how are they related? *In* Miller, M. W. and G. G. Berg (Eds.). Chemical fallout: Current research on persistent pesticides. C. C Thomas, Springfield, Illinois.

DEPARTMENT OF WILDLIFE ECOLOGY, UNIVERSITY OF WISCONSIN, MADISON 53706. 12 MAY 1969.