Organochlorines and Breeding Success in Cattle Egrets from the Mexicali Valley, Baja California, Mexico

MIGUEL A. MORA[1]

Department of Wildlife and Fisheries Biology
University of California, Davis, California 95616
[1]Current Address: Department of Fisheries and Wildlife, Pesticide Research Center,
Michigan State University, East Lansing, Michigan 48824.

Abstract.—I examined breeding success in the Cattle Egret (*Bubulcus ibis*), and analyzed organochlorine residues in eggs collected during 1987 and 1988 in the Mexicali Valley, Baja California, Mexico. DDE was found in all 50 of the eggs (geometric mean 3.2 ppm ww); other organochlorines also were detected but at lower concentrations. Eggshell thickness was negatively correlated with DDE (N = 50, P < 0.01, r = –0.42), and with Aroclor 1260 (N = 40, P < 0.01, r = –0.51). The mean eggshell thickness in 1987-88 was 9.3% thinner than the mean for pre-1953 museum clutches, but 8.8% thicker than the mean for Cattle Egret eggshells collected in 1974 from the Salton Sea, California. The mean clutch size for 1988 was similar to that of the Salton Sea heronry in 1974, but 14% to 23% lower than the mean clutch size observed in Texas and the eastern United States. The productivity (number of young raised to three weeks of age per breeding adult) was 32% higher than for the Salton Sea area, but 34% to 58% lower than for Texas and Florida. Minor shell thinning and moderately low egg failures indicated that hatching success was probably not significantly affected by DDE or other organochlorines, thus, the relatively high nestling mortality observed in marked nests (49%) might be associated with unmeasured ecological factors rather than with high DDE levels. *Received 7 January 1991, accepted 8 April 1991.*

Key words.—Baja California, Breeding success, *Bubulcus ibis*, Cattle Egret, Organochlorines, Wading birds.

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Wading birds have been suggested as good biological indicators of environmental pollution because of their position in the food chain, their wide distribution, and the ease with which they can be sampled (Custer and Osborn 1977). The Cattle Egret (*Bubulcus ibis*) may be a good indicator of pollution resulting from agriculture because of its insectivorous diet (Siegfried 1971) and its habit of feeding in agricultural areas or near irrigated fields (Mora 1990). Birds feeding in agricultural areas may accumulate insecticides at harmful levels, either by direct contact or by the consumption of prey contaminated with such pesticides (Pimentel and Levitan 1986).

Previous studies of organochlorine insecticides in Cattle Egret carcasses from the Mexicali Valley (Mora 1990) reported concentrations of up to 20 parts per million wet weight (ppm ww) of DDE [2,2-bis -(4- chlorophenyl) -1,1-dichloroethene]. Historically, high DDE concentrations have been directly related to impaired breeding success in many birds because of eggshell thinning and increased egg breakage (Anderson and Hickey 1972); DDE concentrations of 8 ppm ww in eggs of Black-crowned Night-Herons (*Nycticorax nycticorax*; Henny *et al.* 1984), and 3 ppm ww in eggs of Brown Pelicans (*Pelecanus occidentalis*; Blus *et al.* 1974) have been observed to cause a reduction in their reproductive success.

In the Mexicali Valley, the Cattle Egret nesting season coincides with the time of the year (late spring-early summer) when the application of insecticides is higher than during other periods (D. Covarrubias pers. comm.). In this study I examine the concentrations of organochlorines in eggs of Cattle Egrets breeding in an agricultural area where pesticides are intensively used and the relationship between the annual breeding success of Cattle Egrets and organochlorine concentrations in eggs and carcasses.

STUDY AREA AND METHODS

The heronry was approximately 42 km southeast of the city of Mexicali, Baja California, Mexico (32°15′, 115°08′; Mora 1989). No other heronries were within a 40 km radius. Cattle Egrets, Snowy Egrets (*Egretta thula*), and Great Egrets (*Casmerodius albus*) nested at the heronry which was surrounded by cotton and asparagus fields. The adjacent fields were sprayed at least twice during the breeding season. Information on feeding flight directions, agricultural habitat use and foraging success of Cattle Egrets is given in Mora (1990).

I collected Cattle Egret eggs during two breeding seasons from nests with complete clutches and at an early stage of incubation. Forty eggs were taken on 8 June 1987 and 10 eggs on 8 July 1988. Immediately after collection, the eggs were weighed, measured, and the contents were removed and kept frozen until chemical analysis. Egg volumes were calculated using Hoyt's formula: $V = K_vLB^2$, where L = length, B = breadth, and $K_v = 0.51$ (Hoyt 1979); three readings of dried shell thickness were taken.

The extraction, cleanup, gas-liquid chromatography and mass spectrometry (GC/MS) procedures are in Mora *et al.* (1987). Egg homogenates were analyzed for a variety of organochlorines (see Table 1). Organochlorine residue data were transformed to common logarithms for statistical analysis with linear methods (Neter *et al.* 1985). If the frequency of detection was greater than 50%, the value of one-half the lowest limit of detection was substituted for undetected residues (Haas and Scheff 1990). Differences in mean organochlorine concentrations in eggs within and between the two breeding seasons were determined by analysis of variance (ANOVA) and by two sample comparisons of those chemicals that were present in more than 50% of the samples. Differences in clutch size and eggshell thickness between years were also determined by two-sample procedures. Simple linear regression determined the relationship between shell thickness and DDE or PCBs measured as Aroclor 1260.

Cattle Egret nests were visited on 8 June, 12 June, 19 July, and 10 September 1987; in 1988, 30 marked and over 1000 unmarked nests were checked every three to four days from 7 July to 29 August. During each visit, I recorded the clutch size, number of unhatched eggs, number and age of young, number of abandoned or destroyed nests, and number of dead chicks in each of 1030 nests. I observed the unmarked nests from a distance of approximately 20 m from the edge of the heronry. In 1987, the number of young fledged per nest was estimated from the observation of 360 unmarked nests. Nesting success for 1988 was calculated using the Mayfield method (Mayfield 1975) from data collected from 30 randomly marked nests. Mayfield's method gives the maximum likelihood estimation or the probability $\hat{p}$ of survival of at least one young/nest, from the beginning of the incubation period up to fledging. Conventional nesting success, defined as the percent of the number of eggs laid that produced fledged young (at least three weeks of age, Siegfried 1972), and productivity were calculated from the marked nests for comparison with other reports.

RESULTS

Organochlorine residues

DDE was found in all 50 of the eggs collected during both breeding seasons at the Mexicali Valley at significantly higher levels (ANOVA, $P < 0.001$) than any other of the organochlorines detected (Table 1). For residues found in both years, no significant differences in organochlorine concentrations were found between years. Thirty-eight percent of the eggs from 1987 and 40% of the eggs from 1988 had DDE concentrations above 5 ppm ww. Except for heptachlor epoxide, all the organochlorines were detected in more than 50% of the eggs collected in 1987; however, only DDE, HCB, endosulfan, and dieldrin were detected in more than 50% of the smaller sample (N = 10) of eggs collected in 1988 (Table 1). DDE concentrations in Cattle Egret eggs from both years were not significantly different (two-sample t-test, $P = 0.28$) from DDE concentrations in Cattle Egret carcasses collected at the Mexicali Valley during the summer of 1986 (Mora 1990). The DDE:DDT ratio in eggs was 106.

Summary statistics for the eggs collected for organochlorine analysis are in Table 2. Clutch size and mean eggshell thickness were not significantly different between years (Mann-Whitney U test, $P > 0.05$). Egg weight obtained in the field was similar ($\leq 5\%$) to the volume values obtained with Hoyt's method (Hoyt 1979). Eggshell thickness was negatively correlated with DDE ($P < 0.01$, $r = -0.42$, Fig. 1), and with Aroclor 1260 concentrations ($P < 0.01$, $r = -0.51$). DDT concentrations in Cattle Egret eggs were low, but were positively correlated with DDE ($P < 0.001$, $r = 0.77$). DDE and Aroclor 1260 were also strongly correlated ($P < 0.001$, $r = 0.82$).

Breeding success

The mean clutch size for 1988 was smaller (2.6 ± 0.63), and significantly different (Mann-Whitney U test, $P < 0.05$) from the mean clutch size for 1987 (2.9 ± 0.44. Hatching success was 89.6% of the total number of eggs laid in 1988, and 23 (76.7%) of the 30 marked nests were successful in raising at least one young to three weeks of age. During 1988 the proportion of marked nests that were successful in raising at least one young to three weeks of age, calculated with the Mayfield method was 0.79. I observed the marked nests for a total of 1,167 nest-days (30 nests for an average of 39 days, range 15-46 days). The probability of survival per nest-day was $\hat{p} = 1-(30-23)/1167 = 0.994$. Nest success (the probability of survival of at least one young per nest from the start of the laying period up to at least three weeks

Table 1. Organochlorine residues (ppm ww) in Cattle Egret (*Bubulcus ibis*) eggs from the Mexicali Valley.

	1987 (N = 40)		1988 (N = 10)	
Chemical[1]	Frequency	Mean[2]	Frequency	Mean[2]
HCB	32	0.015 (0.012-0.02)	10	0.024 (0.016-0.032)
HCH	37	0.014 (0.012-0.017)	4	0.016 (0.009-0.031)
Oxychlordane	21	0.010 (0.008-0.013)	2	0.021
Hept. epoxide	17	0.010 (0.006-0.017)	ND	—
Endosulfan	33	0.018 (0.014-0.022)	5	0.022 (0.015-0.034)
p,p'-DDE	40	3.22 (2.3-4.5)	10	3.49 (2.1-5.7)
p,p'-DDD	25	0.017 (0.011-0.024)	ND	—
p,p'-DDT	39	0.033 (0.024-0.045)	2	0.017
Dieldrin	38	0.034 (0.023-0.048)	10	0.043 (0.031-0.061)
Endrin	25	0.016 (0.011-0.021)	ND	—
Aroclor 1260	31	0.348 (0.244-0.495)	ND	—

[1]Organochlorine residues were confirmed with GC/MS in 10% of the samples. Lowest limit of detection was 0.001 ppm for organochlorine pesticides and 0.050 ppm for PCBs.
[2]Geometric means and 95% CI, ND = Not detected.

of age) was obtained with the one-day probability $\hat{p}$, and the average number of days observed (39), or more exactly $\hat{p}^{38.9}$. Conventional nest success (Siegfried 1972) was lower at 0.45, resulting from only 35 young raised to three weeks of age or older from a total of 77 eggs laid; productivity, the number of young raised to three weeks of age per breeding adult was 0.59, or 1.17 young per nesting attempt.

During 1987 it was only possible to estimate the number of young raised to three weeks of age per nest (2.2 ± 0.4) from the observation of 360 unmarked nests. During 1988 and for comparisons with 1987, a similar estimate based on the observation of 1016 unmarked nests provided 1.5 ± 0.3 young raised to three weeks of age per nest. The peak departure of young from nests (at about three weeks of age) during 1988 occurred during the second half of July.

Only in a few cases was it possible to observe dead young in nests. However, from marked nests in 1988 I observed that of the 69 eggs that hatched only 35 young survived to at least three weeks of age, resulting in 49.3% nestling mortality, and 10.4% unhatched eggs. Additionally, I checked the contents of 766 nests toward

Table 2. Clutch size and dimensions (means ± 1 SD) of Cattle Egret eggs collected for organochlorine analysis (sample size in parentheses).

	1987 (40)	1988 (10)
Clutch size	2.9 ± 0.4	2.8 ± 0.8
Egg mass (g)	24.9 ± 2.3	23.4 ± 3.1
Volume (ml)	25.0 ± 2.1	24.7 ± 2.5
Egg length (mm)	45.3 ± 2.2	45.4 ± 1.8
Egg breadth (mm)	32.9 ± 1.2	32.6 ± 1.3
Shell thickness (mm)	0.217 ± 0.019	0.205 ± 0.017
Lipid (%)	6.3 ± 1.4	6.1 ± 1.9
Moisture (%)	80.9 ± 1.4	81.6 ± 1.2

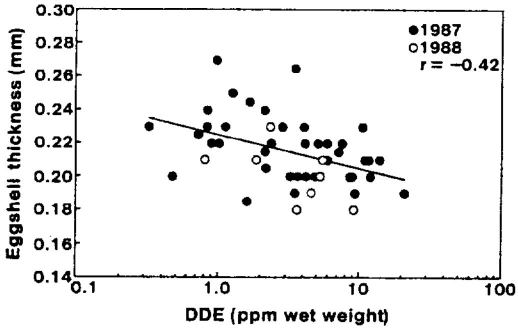

Figure 1. Relationship between eggshell thickness and log of DDE residues in Cattle Egret eggs from the Mexicali Valley.

the end of the breeding season and found that only 3.5% of nests had dead young, 0.5% had unhatched eggs, and a few had dead adults.

DISCUSSION

Organochlorines and eggshell thickness

The presence of high concentrations of DDE and relatively low concentrations of DDT in eggs of Cattle Egrets from the Mexicali Valley strongly suggests that DDE is still present in the environment because of heavy past use on agricultural areas in northwest Mexico. The DDE concentrations in eggs were higher but not significantly different from the DDE concentrations in bird carcasses from previous years (Mora 1990), suggesting that the patterns of exposure of Cattle Egrets to DDE were the same for the three years of study. Organochlorine residues in eggs normally reflect body burdens or are directly correlated (Keith and Gruchy 1972).

DDE concentrations in Cattle Egret eggs from the Mexicali Valley were also lower than those recently recorded in Great Egret (geometric mean = 24 ppm ww) and in Black-crowned Night-Heron (8.6 ppm) eggs collected in 1985 at the Salton Sea (Ohlendorf and Marois 1990). Great Egrets are fish-eating birds and would be expected to have higher organochlorine residues than Cattle Egrets which are mostly insectivorous. Cattle Egrets have usually been observed with lower organochlorine residues in eggs or carcasses than other egrets (Ohlendorf *et al.* 1981); nonetheless, DDE levels above 8 ppm ww were observed in 22% of the Cattle Egret eggs from Mexicali. DDE levels of 8 ppm ww in eggs caused shell thinning and egg breakage in Black-crowned Night-Herons (Henny *et al.* 1984), and 3.4 ppm ww in eggs of Brown Pelicans had the same effect (Blus *et al.* 1974). However, the eggshell thinning effects of pollutants have been variable among birds: gallinaceous birds have shown the least and raptorial and fish-eating birds the most sensitivity (Anderson and Hickey 1972, Cooke 1973).

The negative correlation between eggshell thickness and DDE observed in this study suggests that DDE induces eggshell thinning in Cattle Egrets and that breeding failures may result. The mean eggshell thickness of Cattle Egret eggs from the Mexicali Valley (overall mean = 0.215 mm) was 9.3% thinner than the mean shell thickness (0.237 mm) of pre-1953 museum clutches (20 eggs from five clutches), and 8.8% thicker than the mean eggshell thickness (0.194 mm) of 53 Cattle Egret eggs collected in 1974 at the Salton Sea in southern California (Platter 1976, pers. comm. to D. W. Anderson). DDE concentrations in eggs from the Mexicali heronry (see Table 1), however, were higher than those from the Salton Sea (1.7 ± 0.3; Platter 1976, pers. comm. to D. W. Anderson), although the original data were not available for statistical comparisons. This difference in DDE concentrations between the two areas might be explained by the more recent use of DDT in the Mexicali area, or by differences in the analytical procedures.

The high frequency of low levels of DDT in Cattle Egret eggs and the high DDE:DDT ratios suggest that the DDT concentrations observed in eggs might be the result of high concentrations in the soil due to past, rather than current use. In 1986, 536,836 kg of insecticides were used on cotton in the Mexicali Valley of which 51.4% were organophosphates and 19% were organochlorines (predominantly endosulfan; D. Covarrubias pers. comm.). DDT was not used in the Mexicali Valley during the time of this study; DDT (approximately 275,000 kg) was last used in Baja California, Sonora, and Sinaloa during 1978 (Fertilizantes Mexicanos 1981).

Other organochlorine residues also occurred frequently, but were present at low levels and probably do not represent a threat to Cattle Egrets.

Clutch size and breeding success

The mean clutch size of Cattle Egrets breeding at the Mexicali Valley was similar to the clutch size reported for Cattle Egrets nesting in the Salton Sea in southern California (Platter 1976), an area close (about 90 km) to my study site. Arendt and Arendt (1988) suggested that positive correlations between clutch size of Cattle Egrets and latitude existed; however, the mean clutch size for the Mexicali heronry was 14% to 23% smaller than the mean clutch size observed in other heronries established at similar latitudes, thus, such relationships may not be clear (Telfair 1983). Other factors such as food availability, nesting density, competition for nests, and toxicant effects may be more important in determining clutch size (Maxwell and Kale 1977). Thus, smaller clutch sizes at the Mexicali heronry might have resulted from overcrowding, higher nest density, and competition for nest sites; food was not a limiting factor (see Mora 1990). Clutch size variation also occurs during the breeding season and earlier clutches are usually larger than later clutches (Siegfried 1972, McKilligan 1985). The clutch sizes at the Mexicali heronry were determined when the breeding season was already underway, rather than from the onset of nesting. Since I observed only 9.3% shell thinning and relatively low egg losses (10.4%), the DDE concentrations in eggs probably had no effect on clutch size.

Nest success (Siegfried 1972) of Cattle Egrets at the Mexicali Valley during 1988 was 44% higher than the nesting success observed at the Salton Sea heronry during 1974 (Platter 1976). Productivity at the Mexicali Valley was also 32% higher than at the Salton Sea; it was similar to the productivity of 0.56 observed in South Africa (Siegfried 1972); and 34% to 58% lower than the productivity of 0.9 in Australia (McKilligan 1985), 1.2 in Texas (Telfair 1983), and 1.4 in Florida (Jenni 1969). Cattle Egrets in these areas may have been more productive because they had larger clutches than Cattle Egrets in the Mexicali heronry, and a direct relationship between clutch size and brood size has been observed (McKilligan 1985).

A combination of factors may have been involved in the somewhat high nestling mortality observed in the marked nests. Predation by Black-crowned Night-Herons and one Brown Pelican (Mora 1989), starvation (Siegfried 1972), and siblicide by older siblings (Ploger and Mock 1986) all likely contributed to nestling loss. Mortality of nestlings may have also increased because of some disturbance during my visits inside the heronry, since three of the marked nests were destroyed later in the season after a few visits. Increased mortality as a result of human disturbance at colonies of colonial nesting birds has been reported by various investigators (Boellstorff *et al.* 1988, Henny *et al.* 1989).

In summary, the data from the 1987 and 1988 breeding seasons suggest that Cattle Egret populations are well established in the Mexicali Valley and that their breeding success was not seriously affected by DDE or other organochlorines. However, Cattle Egrets feeding around irrigated agricultural areas, which are frequently sprayed with insecticides, may be more likely to accumulate higher chemical residues than Cattle Egrets inhabiting pristine or non-agricultural areas.

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