DDE Still High in White-faced Ibis Eggs from Carson Lake, Nevada

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Abstract.—White-faced Ibis (*Plegadis chihi*) eggs collected in 1996 at Carson Lake, Nevada, showed no decrease in p,p´-DDE (DDE) concentrations from levels in 1985 and 1986 which is contrary to DDE patterns shown for most avian species. An estimated 40-45% of the population was adversely affected by DDE in 1985, 1986, and 1996 with a probable net loss of about 20% of the expected productivity. One segment of the nesting population at Carson Lake in 1996 averaged 18.3% eggshell thinning, although the mean for the whole population is not known. Obvious population declines of White-faced Ibis have not been reported, although quantitative population data are incomplete; however, the excellent and predictable food sources on the breeding grounds in Nevada (due to flood irrigation by farmers) appear to contribute to a high reproductive potential. While adverse consequences of DDE were not documented at the population level, it is important to locate the source(s) of the DDE/p,p´-DDT (DDT). Results of a previous study showed that prey from the breeding grounds were not contaminated with DDE/DDT. The White-faced Ibis DDE/DDT loads are suspected to originate from localized areas on the wintering grounds and/or staging areas. Use of satellite transmitters placed on nesting birds is proposed to locate the source of the DDE/DDT.
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White-faced Ibis (*Plegadis chihi*) generally feed in wet areas, including marshes, swamps, and flooded agricultural fields, as well as along the edges of ponds, lakes, and streams. They are colonial nesters, extremely social, and usually feed in large aggregations. Notable nesting colonies of this western species are located at suitable marshes in the Great Basin including Great Salt Lake, Utah; Ruby Lake, Nevada; Lower Klamath Lake, California; Malheur Lake, Oregon and Carson Lake-Stillwater, Nevada. The species was listed by the U.S. Fish and Wildlife Service as a migratory nongame bird of management concern in 1987 due to its restricted nesting habitat and potential vulnerability to pesticides.

Earlier contaminant research was conducted at Carson Lake, a State Wildlife Management Area (WMA) near Fallon, Nevada (Henny *et al.* 1985, Henny and Herron 1989). In these studies, the White-faced Ibis was the only wading bird in the Great Basin that failed to show a downward trend in p,p´-DDE (DDE) residues in eggs from 1979 to 1983 (Henny *et al.* 1985). Furthermore, DDE residues were about the same in White-faced Ibis from Utah several years earlier (Capen 1978). Detailed reproductive studies at Carson Lake in 1985 and 1986 showed that DDE was related to fewer young produced per nesting attempt, fewer young produced per successful nest, and eggshell thinning (Henny and Herron 1989). As DDE in eggs increased to >4 ppm (wet weight), and especially >8 ppm, productivity decreased and the incidence of cracked eggs increased.

The purpose of the paper is to: (1) compare DDE, other organochlorine pesticides, mercury and polychlorinated biphenyls (PCBs) in 20 eggs collected in 1996 with earlier data (1985 and 1986) from Carson Lake, (2) evaluate 1996 eggshell thickness in relation to DDE concentrations, and (3) discuss current DDE/p,p´-DDT (DDT) findings with respect to other species and management options.

METHODS

White-faced Ibis nest in several population segments at the Carson Lake colony (39°20'N, 118°40'W). As reported in the earlier investigation (Henny and Herron 1989), nesting within each population segment or subcolony at Carson Lake was synchronized (egg laying by members of the segment within a few days of each other) and usually each segment was more than a week out of synchrony with the next segment (Table 1). Where and when nesting segments are formed remains unknown. Nesting segments may represent age classes or perhaps population components wintering or staging in different localities.

Table 1. Timing of clutch completion and organochlorine (ppm, wet weight) and mercury residues (ppm, dry weight) in White-faced Ibis eggs from various nesting segments at Carson Lake, Nevada, 1985, 1986 and 1996.

	Clutch completion			DDE ppm		Occurrence[a]								Mercury (ppm)	
Year	Mean date	Range	N	Geo. mean	High	DDE > 4ppm	DDT	Dieldrin	HE	Chlordane[b]	Toxaphene	HCB	Endrin	Geo. mean	> 1
1985[c]	23 Apr	19-25 Apr	40[d]	3.43	21	25 (63%)	7 (18%)	25 (63%)	0	0	1 (3%)	NA	6 (15%)	0.22	1 (5%)
1985[c]	21 May	20-23 May	20	1.87	9	6 (30%)	4 (20%)	4 (20%)	1 (5%)	0	0	NA	4 (20%)	0.77	6 (30%)
1986[c]	19 Apr	15-21 Apr	20	3.23	28	11 (55%)	11 (55%)	7 (35%)	0	4 (20%)	9 (45%)	3 (15%)	4 (20%)	0.47	1 (5%)
1986[c]	1 May	30 Apr-5 May	20	1.70	29	7 (35%)	8 (40%)	4 (20%)	4 (20%)	3 (15%)	4 (20%)	10 (50%)	6 (30%)	0.43	1 (5%)
1986[c]	15 May	30 Apr-21 May	20	2.10	19	6 (30%)	7 (35%)	7 (35%)	4 (20%)	0	1 (5%)	7 (35%)	3 (15%)	0.70	3 (15%)
1986[c]	21 May	16-26 May	20	1.53	14	4 (20%)	7 (35%)	4 (20%)	4 (20%)	2 (10%)	0	6 (30%)	3 (15%)	1.09	11 (55%)
1996	7 May	5-11 May	20	2.66	12	9 (45%)	12 (60%)	0	0	1 (5%)	NA	2 (10%)	0	0.72	5 (20%)

NA = not analyzed, HE = heptachlor epoxide, HCB = hexachlorobenzene.

[a]Incidence of contaminants in eggs ≥ 0.10 ppm (the detection limit for 1985-86) for comparative purposes, but the detection limit was actually 0.01 ppm in 1996.

[b]Includes oxychlordane, *trans*-nonachlor, and *cis*-nonachlor.

[c]Adapted from Henny and Herron (1989).

[d]Two population segments were initially sampled, but they were part of the same nesting segment. Only 20 eggs analyzed for mercury.

One egg was collected at random from 20 nests in a population segment from the Spring Pond Unit at Carson Lake, Nevada, on 10 May 1996. Twelve of the eggs were fresh (no development) and 8 showed slight (a few days) incubation. The nests were over water and located in bulrush (*Scirpus acutus, S. maritimus*), but were not followed through the nesting cycle to evaluate reproductive success.

Egg contents were placed in chemically cleaned glass bottles and frozen. All 20 eggs were analyzed for organochlorine pesticides, their metabolites, and polychlorinated biphenyls (PCBs) at the Analytical Control Facility of the Patuxent Wildlife Research Center (PWRC), Laurel, Maryland. The analytical methods, including preparation, Soxhlet extraction, and lipid removal are described by Cromartie *et al.* (1975). Glass extraction thimbles were used. The silica gel separation of the pesticides from PCBs was different from the above reference in that 4 fractions were used instead of 3 to enable the separation of dieldrin and endrin from the rest of the pesticides. The pesticides in each fraction were quantified with a gas-liquid chromatograph (GLC), equipped with a 63Ni electron capture detector. The GLC column used was a 30m MEGABORE coated with a 1.0 micron film of 7% cyanopropyl, 7% phenyl polysiloxane. Residues in 2 of the samples were confirmed by gas chromatography/mass spectrometry (GC/MS). The nominal lower limit of detection was 0.01 ppm for pesticides and 0.05 ppm for PCBs based on a 10 g aliquot wet weight. We converted contents of eggs to an approximately fresh wet weight using egg volume (Stickel *et al.* 1973); all organochlorines in eggs were expressed on a fresh wet-weight basis.

The 20 eggs were also analyzed for mercury at PWRC. One-gram aliquots were digested under reflux in sulfuric and nitric acids as described by Monk (1961). The determination was performed by cold vapor atomic absorption spectrophotometry using a Spectro Products mercury analyzer equipped with a Varian VGA-76 vapor generation accessory. The nominal lower limit of detection was 0.05 ppm on a wet-weight basis (≈0.25 ppm dry weight). Mercury residues are presented on a dry-weight basis. Percent moisture was determined by allowing a sample to dry 24 hours in an oven at 200 degrees Fahrenheit. Samples were then put in a desiccator to cool and then weighed.

The lower quantification limit was halved for samples in which a contaminant was not detected. This value was used to calculate geometric means when ≥ 50% of the samples contained detectable residues. Shell thickness (including membranes) was measured at 3 sites on the egg equator with a micrometer graduated in units of 0.01 mm; the mean of the measurements was used to represent the thickness of the shell. Measurements of historic White-faced Ibis eggs were obtained from Capen (1977).

RESULTS

DDT and Metabolites in Eggs

The 1996 egg collection came from a May nesting segment (mean clutch completion date, 7 May). The DDE and DDT egg residues from May 1996 show no evidence of a decrease when compared to eggs collected in May 1985 and May 1986 (Table 1). Instead, the DDE geometric mean (2.66 ppm), the incidence of DDE ≥ 4 ppm (45%), and the incidence of DDT > 0.10 ppm (60%) were all higher. In fact, with the lower detection limits in 1996, DDT was found in all eggs. However, the highest DDE concentration in May 1996 (12 ppm) was not as high as in May 1985 and 1986 (29 ppm).

Other metabolites of DDE and DDT were also detected with the lower detection limits in 1996. Three eggs that contained the highest o,p´-DDD (0.33, 0.33, and 0.29 ppm) also contained the highest p,p´-DDE (10.5, 10.0, and 12.3 ppm) and these eggs also contained some of the highest p,p´-DDT (0.16, 0.19, and 0.29 ppm). Six other eggs also contained o,p´-DDD (0.01 to 0.07 ppm), 5 eggs contained p,p´-DDD (0.01-0.08 ppm), and 1 egg, o,p´-DDE (0.01 ppm).

Eggshell Thickness and DDE

Eggshell thickness was significantly related to $\log_{10}$-transformed DDE in the eggs collected in 1996 (Fig. 1). This relationship was similar to the earlier findings for White-faced Ibis at Carson Lake during 1980-83 ($\hat{Y} = 0.298 - 0.029 \log_{10}X$, $r_{94} = -0.628$, $P < 0.001$) and during 1985-86 ($\hat{Y} = 0.286 - 0.028 \log_{10}X$, $r_{138} = -0.665$, $P < 0.0001$) (Henny and Herron 1989). The mean eggshell thickness of 0.267 mm in the sampled nesting segment from 1996 was 18.3% below the pre-DDT era norm of 0.327 mm reported from Utah and California by Capen (1977).

Other Organochlorines and Mercury in Eggs

Dieldrin, the chlordanes, hexachlorobenzene (HCB) and endrin were seldom detected in 1996 at levels above 0.10 ppm (the detection limit for the 1985-86 data) whereas they were regularly detected a decade ago (Table 1). However, with the detection limit in 1996 being 0.01 ppm, 15 of 20 eggs contained detectable concentrations of dieldrin (geometric mean, 0.03 ppm), 13 of 20 endrin (geometric mean, 0.02 ppm), 12 of 20 oxychlordane (geometric mean, 0.01

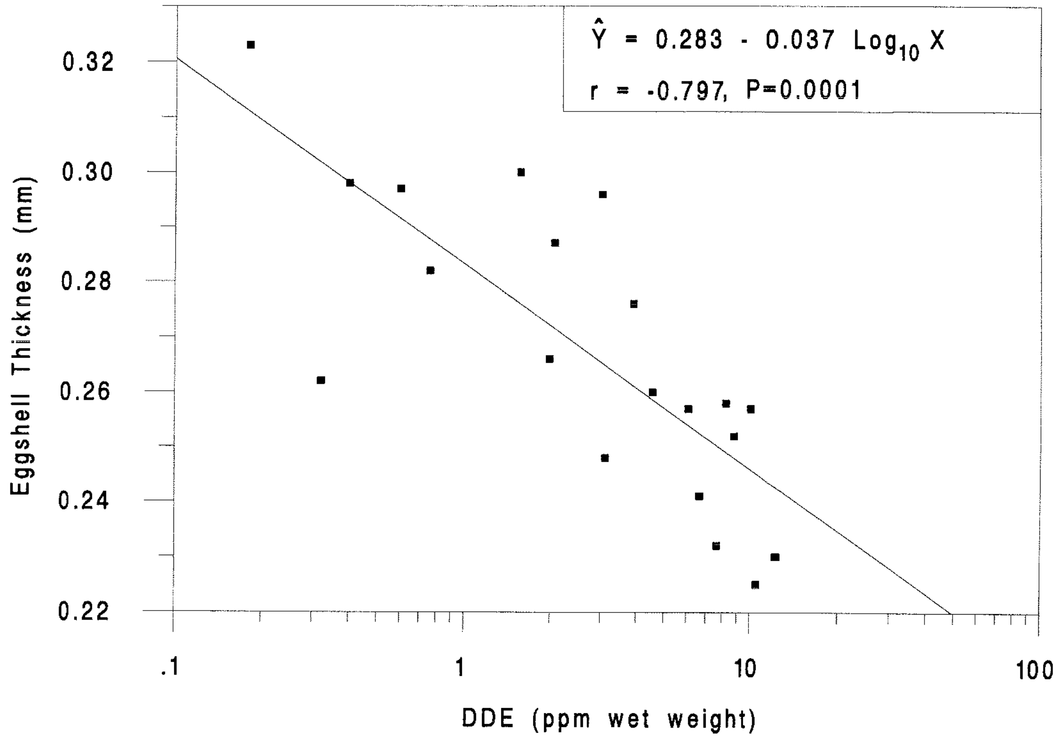

Figure 1. The relationship between DDE (wet weight) and eggshell thickness (mm) for White-faced Ibis from Carson Lake, Nevada, 1996.

ppm), 14 of 20 *trans*-nonachlor (geometric mean, 0.01 ppm), 11 of 20 *cis*-nonachlor (geometric mean, 0.01 ppm), and 14 of 20 HCB (geometric mean, 0.02 ppm), and 8 of 20 heptachlor epoxide (no geometric mean calculated). No alpha benzene hexachloride (BHC), alpha chlordane, gamma BHC or gamma chlordane were detected. Three eggs contained beta BHC (0.01, 0.01, and 0.03 ppm) and 7 eggs gamma chlordane (0.01 to 0.02 ppm). No PCBs were detected (detection limit 0.05 ppm) and none were reported in 1985 or 1986 (detection limit 0.50 ppm). The eggs collected in 1996 contained mercury (geometric mean, 0.72 ppm) with 20% containing >1.0 ppm.

DISCUSSION

Organochlorine Pesticides and Their Effects

No significant differences in DDE concentrations were detected among 1985 and 1986 nesting segments, but a higher mean DDE concentration and a higher incidence of eggs with > 4 ppm DDE occurred in the earliest (April) nesting segment each year (Henny and Herron 1989). Thus, it seems logical to compare the May residue data from 1985 and 1986 with the May data from 1996. Contamination of DDE in the May series of eggs collected in 1996 showed no decrease from the May levels reported a decade earlier and was nearly as high as the April concentrations reported in 1985 and 1986. Eggshells from a May series of eggs showed 18.3% shell thinning in 1996, and Hickey and Anderson (1968) concluded that ≥ 18% shell thinning was associated with declining populations for many species. Mean shell thinning reported in 1996 may not be representative of the whole population, but was more severe than the combined value for all 1985 and 1986 segments (13.8%). The data obtained from 1 May nesting segment in 1996 are probably not directly comparable to the combined mean for 1985 and 1986, because some population segments had higher and some lower DDE concentrations. Nevertheless, 1 nesting segment in 1996 with ≥ 18% shell thinning is of concern especially with 45% of the eggs containing > 4 ppm DDE (adverse "effect zone" for White-faced Ibis, Henny and Herron 1989). Having 45% of the nests in the "effect zone" for 1996 is remarkably similar to the combined 40% (Henny and Herron 1989) in the "effect zone" in 1985 and 1986, which resulted in a net loss of 20% of the population's expected reproduction due to DDE. Although productivity was not monitored at the nests with eggs collected, the DDE-related loss of young in the May segment studied in 1996 was estimated to be 20% again based upon the productivity/DDE relationships determined in the earlier study.

Census data are difficult to interpret for a wandering species like the White-faced Ibis without complete counts at all nesting areas, and complete counts are not available. No obvious long-term population declines of White-faced Ibis were reported in the Great Basin during the last decade (see Ivey *et al.* 1988, Taylor *et al.* 1989), although oscillating numbers have been reported in long-term studies (see Steele 1984, Henny and Herron 1989). This is not unusual for a species that lives in unpredictable habitat (subject to annual changes in water levels). The Carson Lake colony has continued to fluctuate, but in 1996 (a good water year) population levels were near the 1985 (a good water year) population high (L. A. Neel, Nevada Dept. Wildlife, pers. comm.).

The White-faced Ibis has an extremely high reproductive potential that may buffer or partially buffer DDE- related losses in productivity. The high reproductive potential may be a function of the way the ibis feeds in flood-irrigated farm fields. Earthworms, which form the bulk of their diet, are available in flood-irrigated fields within 15 km of the nesting colony and the White-faced Ibis move from field to field as daily flooding takes place for irrigation purposes (Bray and Klebenow 1988). The predictable and abundant food source, although in different fields each day, plus stable over-water nesting sites in emergent vegetation during good water years, permit the species to potentially increase the number of young produced per nest (perhaps much higher than in times before farmers flood irrigated). The wandering trait of this species also permits them to move away from unsuitable areas during drought years, and find more suitable nesting sites.

Measures of reproductive success in long-legged wading birds are known to vary widely depending upon species, location, degree of predation and environmental conditions (e.g., Bildstein *et al.* 1990). The high productivity hypothesis in White-faced Ibis was based upon the excellent productivity at nests studied with ≤ 4 ppm DDE (below "effect zone") in 1985 and 1986 (Henny and Herron 1989): (1) The mean clutch size was 3.32 eggs, (2) 92% of the nests (N = 71) were successful in producing at least 1 young, and (3) 1.95 young/successful nest were produced to the stage where they leave the nest. Thus, of the eggs laid in successful nests (3.32-1.00 collected) that were incubated (2.32), most (1.95 or 84%) produced young. These rates are high compared to published records for other wading birds, although it is not known how many young must be produced per nesting White-faced Ibis pair to balance mortality. These rates are especially high when compared with a series of Black-crowned Night-Heron (*Nycticorax nycticorax*) studies (Custer *et al.* 1983), and may provide the White-faced Ibis with the ability to compensate for a 20% reduction due to DDE. However, this does not mean that the DDE/DDT issue should be dismissed. It seems logical that other species may be adversely affected too, especially those living near the source of the DDE/DDT accumulated by the White-faced Ibis. Furthermore, if the high production hypothesis is true and if flood irrigation practices change, or long-term regional drought occurs, this White-faced Ibis population could be in trouble from DDE/DDT.

Other organochlorine contaminants were generally low already in 1985 and 1986 and no adverse effects that could be associated with these contaminants were noted

(Henny and Herron 1989). Incidences as well as concentrations of these contaminants were even lower in 1996. In contrast to the organochlorines, which generally showed a pattern of decrease with later nesting segments during the breeding season in the earlier study, mercury was obtained from local prey species in Nevada and showed increased concentrations in later nestings. The mean of 0.72 ppm mercury in 1996 was within the range reported for May nesting segments in 1985 and 1986 (0.43 to 1.09 ppm) which suggests no long-term change in mercury concentrations during the last decade. Henny and Herron (1989) concluded that mercury in 1985 and 1986 was not adversely impacting the production rate of White-faced Ibis. Productivity in Merlins (*Falco columbarius*) and Mallards (*Anas platyrhynchos*) decreased when mercury in eggs exceeded 3 ppm dry-weight (Newton and Haas 1988, Heinz 1979).

Source of the DDE/DDT

Eighteen adult White-faced Ibis were collected near the Carson Lake colony on 27 June 1985, and Henny and Herron (1989) found no organochlorine insecticides in food items obtained from their upper digestive tracts. They concluded that DDE/DDT was not obtained on the breeding grounds in Nevada. They noted that the 5 band recoveries in winter from ibises banded at Carson lake were all from Mexico, primarily the interior agricultural regions. More recently, color-marked White-faced Ibis from Carson Lake have been observed in the Imperial Valley and Colorado River Valley where a portion of the population may be staging or wintering (E. P. Kilchlin, pers. comm.). Both of these areas are known sources of DDE/DDT (Setmire *et al.* 1990).

Twelve of the 20 (60%) eggs collected in 1996 contained $\geq$ 0.10 ppm DDT, and if the detection limit of 0.01 ppm DDT was used, all 1996 eggs contained DDT. Continued detection of DDT (sometimes at especially low DDE:DDT ratios) suggests exposure to recently used DDT (Henny *et al.* 1982); furthermore, the highest DDE residues were accompanied by some of the highest DDT residues.

Although not all White-faced Ibis lay eggs with high concentrations of DDE/DDT, and the predictable excellent food source may compensate for some adverse DDE effects, it is important to locate the DDE/DDT source. Satellite transmitters (19-20g, plus 2g harness) are now available and can be used on adult male White-faced Ibis (mean 697g, range 563-807g [Dunning 1992]) to locate wintering grounds, staging areas and migration routes as well as the timing of migration. This technology combined with blood sampling has been used to evaluate contaminants in migrant Peregrine Falcons (*Falco peregrinus*) (Henny *et al.* 1996), while earlier contaminant studies of Black-crowned Night-Herons used conventional transmitters (Henny and Blus 1986).

The DDE/DDT issue reported here contrasts with the findings for the Peregrine Falcon which winters throughout Latin America and has shown a steady decline in DDE since the late 1970s, including a 32% decrease in DDE residues between 1984 and 1994 (Henny *et al.* 1996). Similarly, the geometric mean DDE residues in eggs of Black-crowned Night-Herons collected in the Lahontan Valley, Nevada steadily decreased from 5.1 ppm in 1980 (Henny *et al.* 1985) to 0.90 ppm (range 0.03 to 5.34 ppm, N = 8) in 1996 (Henny, unpubl. data). The White-faced Ibis DDE/DDT "problems" are probably related to localized agricultural use (perhaps a few crops) and/or heavy historic use where a portion of the White-faced Ibis winter or stage and do not represent a general pattern for most birds in the 1990s.

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