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DDT Contamination of Migrating Birds Using White-faced Ibis as an Indicator Species

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Final Report

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Background

A species of concern to Naval Air Station Fallon (NASF) and other military installations in Nevada, Utah, California, and Oregon is the White-faced ibis (*Plegadis chihi*). These long-legged wading birds feed primarily on invertebrates in the wetlands and irrigated croplands on and surrounding military lands and military operating areas (MOAs). Earnst et al. (1998) state that concern for the species is centered around its small population size and the limited and dynamic nature of its breeding habitat. The U.S. Geological Survey (USGS) and Nevada Department of Wildlife (NDOW) have documented that pesticide contamination occurs in a Great Basin breeding population of the White-faced ibis (Henny and Herron 1989, Henny 1997). A significant segment of the ibis population at Carson Lake, Nevada (adjacent to Naval Air Station Fallon) is burdened with high levels of DDE, the principal metabolite of DDT. A chlorinated hydrocarbon compound widely deployed as a pesticide after the Second World War, its use in the U.S. was banned in 1972. It remained in use elsewhere, including Mexico, although our southern neighbor announced in 1997 that such applications would be completely phased out by 2007. The contamination of ibis at Carson Lake is of a magnitude that threatens reproductive success. Historically, this has resulted in eggshells that were 18% thinner than normal and a 20% decrease in breeding production. DDE levels are highest among the initial nesting cohort, the contamination persists today, and it has been determined that these contaminants are not being acquired in western Nevada. Where and how these birds are being contaminated with DDT was unknown, so wildlife and environmental managers could not take substantive steps toward conserving this population. An increase in eggshell thinning by just 2% could result in extensive reproductive failure, and that could place this species' population on a direct path for listing under the Threatened and Endangered Species Act. Whatever source of DDT is affecting the ibis populations in Nevada likely affects other waterbirds in the region. Breeding cohorts of White-faced ibis elsewhere in the west could also be contaminated with DDT, but no research has been done in other areas to investigate the possibility. Furthermore, whatever source of DDT contamination is affecting this ibis population could also be affecting other waterbirds that intermingle there with the ibis. Those associates may also use MOAs at certain times of the year. From a conservation standpoint, it is very important to learn where these birds are being contaminated before other ibis populations or associates begin to decline. In this case, prevention of a biological problem before it affects mission readiness is worth a great deal more than research and recovery efforts after the situation becomes acute.

Previously the DoD contributed to solving a similar problem that existed with the Swainson's hawk (*Buteo swainsoni*). The decline of Swainson's hawks from many breeding areas had been of concern for a number of years, but it was not until the source of the problem was identified that conservation action could be implemented. We tracked a sample of Swainson's hawks, which breed in N. America (including in many areas of DoD activity), to their wintering grounds in central Argentina. A site visit confirmed the deaths of many individuals there due to monocrotophos (a cholinesterase inhibitor) pesticide exposure. Biologists, agriculturalists, and the agro-chemical industry cooperated to change pesticide use practices in the region used by the hawks, and thus eliminate that threat to the species. Our goal was to make a similar contribution for the White-faced ibis.

It was suspected that White-faced ibis are migrating to s. central California and Mexico to overwinter, and that they are being contaminated there. In a pilot study in 1997, we successfully tracked two White-faced ibis via satellite. In 2000 we outfitted 10 ibis with satellite-received telemetry at Carson Lake under Cooperative Agreement DACA87-99-H-0009, "Definition and Characterization of the Sources of DDT Contamination Currently Impacting White-faced Ibis Populations". We report herein results for that cooperative agreement that were incomplete at the time of the final report. In 2003 we outfitted an additional 10 ibis under this cooperative agreement. Blood samples were collected and analyzed for chemical contaminants, and 10 eggs were collected from the breeding colony in 2000 for similar analyses. We tracked all 20 ibis remotely and, if wintering grounds were determined, individual site visits were made to those locales. Twelve wintering sites were defined, ranging from the northern Central valley of California to near Guadalajara in Mexico's Jalisco State. At those sites we and our collaborators collected invertebrates from ibis foraging areas for analyses and recorded associate avian species present.

Through this project we determined migration routes and wintering areas of sentinel ibis from this troubled population in western Nevada, and a major source of contaminants affecting it. By identifying this source, management efforts can be efficiently directed at the problem, thereby saving effort toward further investigation and misguided management efforts that may not be targeted to the most serious problem. Reduction of this threat should preclude the expensive, disruptive process of listing and management of the ibis as a Threatened or Endangered Species (or population). The identification and reduction of this threat to White-faced ibis will likely also contribute to the effective management of other species of waterbirds that may be exposed to the same source of DDT contamination.

The DoD maintains several bases in Nevada and more in neighboring states. The acreage (Fig. 1) is misleading; the MOAs for these bases are expansive because the areas are largely used for training in military aircraft. In fact, DoD activity in the Great Basin encompasses most of the ibis breeding habitat. The DoD has an obligation to be good stewards of these lands and the animals that inhabit them. By taking the lead in investigating the true sources of contaminants affecting this species, the DoD has played another important role in migratory bird conservation.

Methods

Since the earliest nesting ibis at Carson Lake have the highest occurrence of significant DDE contamination (Henny and Herron 1989, Henny 1997) we targeted that group to better our chances of tracking birds with high DDE blood levels. Surveys to determine the location of the first nesting cohort of White-faced ibis were conducted during late-March/early April 2000 at Carson Lake, Nevada. In mid-late April, visits to the nesting colony were made and we flagged the site and the route between the colony and the boat ramp to facilitate nighttime navigation. In 2003 the target colony was identified by NDOW during spring waterbird surveys. Individuals were captured from an air boat at night by spotlight and dip net, and removed from the net in <one minute as recommended by Schemnitz (1993, 1980). In 2000 we also collected one ibis egg from each of 10 nests for analyses.

Captured individuals were retained in poultry crates, individually weighed and assessed for overall viability, and the best candidates (determined by body mass and overall condition) retained for immediate instrumentation. USGS leg bands were affixed to all captured birds (Gustafson et al. 1997). Blood samples (~1 ml) were obtained from the brachiocephalic vein via syringe and 27-gauge needle (Redig 1993) and stored in a vacutainer. Platform Transmitter Terminals (PTTs) weighing ~20 g (North Star Science and Technology, LLC) were affixed as backpacks (Snyder et al. 1995, Buehler et al. 1995) to selected ibis; neoprene harnesses were individually fitted to each bird. After blood sampling, radio marking, and banding were completed, each bird was released near its capture site. Blood samples were separated by centrifuge. The plasma was drawn off via sterile pipette, frozen in sterile cryogenic vials, and transported on dry ice to the Analytical Control Facility at the USGS Patuxent Wildlife Research Center. All protocols were approved by Boise State University's Institutional Animal Care and Use Committee and conducted under necessary permits acquired from state and federal authorities.

Telemetry via satellites is based on the Service Argos system. Service Argos is a cooperative among the Centre National d'Etudes Spatiales (France), the National Aeronautics and Space Administration (USA), and the National Oceanic and Atmospheric Administration (USA). Argos allows researchers to remotely track natural resources anywhere in the world by marking them with PTTs that transmit at 401.65 MHz. Service Argos estimates PTT locations (Argos 2004) using the principles of Doppler Shift in signal frequency, and distributes locations and sensor data to users. Argos calculates the distribution within which the estimate lies; the standard deviation of this distribution estimates the accuracy of the location, and it is placed in a location class (LC: Z, B, A, 0, 1, 2, 3, in ascending accuracy). Class Z indicates that the location process failed, while class B and A locations were obtained from two and three messages, respectively. Classes 0, 1, 2, and 3 indicate the location was obtained with 4 messages or more. Class B and A location accuracy cannot be estimated because too few messages were received. Error estimation of a class 0 location is higher than 1.5 km. The error estimate (radius) is greater than 1500 m and there is no upper limit; the error could be 50, 100, 500 km. Practically, there are two categories of class 0 locations: 1) locations with errors < 10 km (usually the platform is close to the satellite ground track or random frequency instabilities are observed between messages); and 2) very inaccurate locations, with errors above 50 km (corresponding to out-of-range instabilities from the PTT oscillator). Class 1 locations are estimated at better than 1000 m with a 1500 m radius, and Class 2 at better than 350 m with a 500 m radius. Class 3 locations are considered the most accurate, and are estimated at better than 150 m on both axes, with a 250 m radius.

Location accuracy varies with the geometrical conditions of the satellite passes, the stability of the transmitter oscillator, the number of messages collected, and their distribution in the pass. This means in particular that a given transmitter can have locations distributed over several classes during its lifetime. The error estimation process is not totally independent of the transmitter frequency stability, or of the platform motion which also translates into a frequency shift. It assumes that the frequency is "approximately" stable during the satellite pass. As a consequence, oscillator instability or a fast-moving platform may lead to underestimation of the error. We calculated mean Class 3 locations at wintering sites to use as a starting point in prey collections. Class 1-3 locations (and Class O locations, when properly evaluated in the context of previous and subsequent Class 1-3 locations) were useful in defining larger scale movements.

PTT duty cycles were programmed to initially provide only data necessary to ensure proper operation of the PTT and to transmit more frequently when the birds should be en route to their winter range. In 2000 PTTs were set to operate for six hours each day for the first 6 days. Thereafter, they transmitted for six hours of every 342 hours until October 2000. At that point they were programmed to transmit eight hours of every 77 until batteries were depleted. In 2003 PTTs were set for transmission periods of: 1) 8 hours of every 248 hours until the beginning of November; 2) 8 hours of every 24 hours for three days to restore maximum battery condition; 3) 8 hours of every 111 hours until early March 2004; 4) 8 hours of every 163 hours until mid-May 2004, at which time they would deactivate. Location and sensor data received from Argos were processed by Earthspan and files created (.xls, .dbf, and shapefiles) for use in ArcGIS (ESRI GIS and Mapping Software). Locations were represented in WGS 84 datum.

Sampling of invertebrates at sentinel ibis wintering areas took place between late January and early March, while ibis were still on site. Field technicians traveled to the mean Class 3 location of each ibis that we had successfully tracked to its wintering site, then looked for the closest group of ibis and proceeded to sample the invertebrates upon which they were apparently feeding. There were earthworms (*Lumbricus terrestris* and related subspecies), small and delicate aquatic worms, mealworms, copepods and small insects and their larvae in varying habitats. Tweezers were used in collecting and processing the smaller invertebrates. If earthworms of sufficient size and number were present, a ≥15 ml sample was collected. For the smaller, more difficult to collect invertebrates, a ≥2 ml sample was collected. Samples were rinsed in distilled water, preserved as a composite in chemically cleaned glass bottles, and frozen on dry ice. The GPS location of the collection site, type of habitat in which the ibis were feeding, and other avian species observed to be associated with that site were noted. Samples were then collected similarly at up to four more sites in the vicinity where ibis were feeding, or (in 2004, as explained under Results) where earthworms could be found in proximity to ibis foraging sites. Sample sites were at least 400 m apart unless habitat/land use was radically different, and were sometimes as far as 10 km from the mean Class 3 location. Samples were maintained in a frozen state and transported to the laboratory on dry ice.

Blood, eggs, and invertebrate samples were analyzed for organochlorine pesticides, their metabolites, and polychlorinated biphenals (PCBs). Methods are described in Cromartie (1975). Results are presented here on a wet weight basis.

Results

Capture/Marking

Initial surveys conducted in early April 2000 at Carson Lake to determine the location of the first nesting cohort of White-faced ibis yielded no ibis. However, at follow-up visits we observed nest selection and initiation. In early May, we captured 15 individuals at night from one airboat. Not all individuals were obtained from the same colony, as bulrush at the site was impenetrable by the airboat and we captured ibis only at the margins. Therefore, most individuals were secured from adjacent areas in the Sprig Ponds section of Carson Lake. Males were targeted because they are larger and therefore better able to successfully carry the transmitter package. We applied PTTs to 10 of these ibis, and took blood samples for chemical analyses. Additionally, ten eggs were collected from different nests at the first nesting colony for Dr. Charles Henny (USGS) under his permit.

In late May 2003 we captured ~70 ibis from the Big Water section of Carson Lake, using two airboats. Ten individuals were processed as in 2000. The 20 ibis we outfitted with PTTs in 2000 and 2003 varied in weight from 600-677 g.

Data analysis / Mapping

After radio marking the ibis, location data were collected by the Argos Satellite System and distributed to Earthspan electronically. In both years receptions became sporadic soon after marking. Engineers at the PTT manufacturer theorized that the length of the duty cycle specified early in the study affected battery performance, and that when more frequent transmissions began, we would again receive location data. For the most part, that proved to be the case. Fifteen of the 20 PTTs began to produce good locations after the change in duty cycle, and we successfully tracked 12 ibis to their wintering sites. PTT sensor data confirmed that the other three ibis either died or shed their transmitters en route.

Wintering sites (Fig. 2) ranged between California's northern Central Valley and Mexico's Jalisco State.

Collection of invertebrates at wintering sites

We collected 17 invertebrate samples at four ibis wintering sites in California's Central Valley during early February 2001; 7 of those samples were earthworm composites. We arranged for a collaborator, Dr. Eduardo Santana to collect five miscellaneous invertebrate samples near Guadalajara, Jalisco State, Mexico in early March 2001. Those samples were ultimately ruined when delayed during shipment by a Customs official. Santana revisited the site in late January 2002 and secured five replacement samples. We could not visit the Colorado River Delta (Baja Norte State, Mexico) wintering sites of two 2000 ibis in early 2001, because permits were not approved before the ibis had returned north.

Analyses of 2001 collections revealed elevated DDE levels only in some earthworm samples, so further collections at wintering sites focused (43 of 47 samples collected in 2004) on those invertebrates. In early February 2004 we collected 24 samples in California's Central Valley; 11 from two wintering sites of 2003 subjects and 13 from resampling at wintering sites of three 2001 subjects. We arranged for a collaborator, Dr. Jaqueline Garcia, to collect samples from various sites in Mexico. In mid-February 2004 she collected 15 samples from the wintering areas of three subjects (two from 2000, one from 2003) in the Colorado River Delta, Baja Norte State. In late February 2004 she collected five samples from a site in Guanajuato State, and in early March she collected three samples from a site in coastal Sinaloa State.

Contaminant analyses

All egg and blood analyses, and the 2001-2002 invertebrate analyses were conducted by the Analytical Control Facility at the USGS Patuxent Wildlife Research Center. 2004 invertebrate analyses were conducted by the Great Lakes Institute for Environmental Research at the University of Windsor, Ontario, Canada.

Six of ten eggs collected in 2000 had >4 ppm DDE (Table. 1). Seventeen of our twenty subjects had detectable blood DDE levels (Table 2), ranging from 0.011 to 0.990 ppm. Detectable levels <0.15 ppm were considered low, 0.15 ppm to 0.24 ppm medium, 0.25 ppm to 0.49 ppm high, and >0.50 ppm very high. Therefore, among 20 samples, six were very high, two high, two medium, seven as low, and 10 low.

Among 17 non-earthworm composite samples collected at six sites, 14 contained <0.01 ppm DDE, with the highest level only 0.042 ppm. Thus, the concentrations in the non-earthworm composites were all considered low, and of limited value in assessing regional contaminant patterns. However, results of the 52 composites of earthworms (a most important part of their diet [Henny and Herron 1989]) collected at 11 wintering sites (Table 2) clearly show DDE patterns among the wintering ranges. Mean DDE concentrations varied from 5.73 to 339.87 ppb, with three sets of samples showing very high means (range 197.80 - 339.87 ppb).

Discussion and Conclusions

Egg and blood analyses showed that the incidence of DDE contamination in Carson Lake ibis remains high. We successfully tracked four ibis displaying very high blood DDE levels at capture (range .623 - .911 ppm) to their wintering sites; three wintered within a small area of the Mexicali Valley in the Colorado River Delta, Baja Norte State, Mexico. Based on the diverse wintering locales of other study subjects and their corresponding blood DDE levels we thought it likely that, if we were to identify a primary source of DDT contamination through our study plan, it would be in the aforementioned area. DDE levels in earthworms below 10ppb were considered low, and of the 37 samples we collected near wintering sites outside the Colorado River Delta, 16 fell into that category. Of the other 21 (range 10.22 - 98.86 ppb), only three had levels above 42 ppb. The three ibis in our suspect area wintered within a circle having a radius of only 29 km that was centered 39 km SSE of Mexicali, Mexico. The range of DDE found in earthworms near wintering sites in that area was 32.5 to 435.7 ppb, with a mean of 270 ppb. Fourteen of fifteen samples displayed levels above 145 ppb, confirming the pervasive nature of contaminated ibis prey within the area.

Harris et.al (2000) demonstrated that continued high DDE levels among earthworms in Canadian fruit orchard soils was resulting in high DDE levels in American robins (*Turdus migratorius*) and their eggs 20 years after DDT had last been used there in orchards.

We also looked at the migrations of the aforementioned ibis with very high blood DDE levels to determine whether they spent significant time en route in other areas that may warrant scrutiny:

- Ibis 41308 (Fig. 3) spent at least 10 days in California’s Imperial Valley, to the south of the Salton Sea and just north of the contaminated area in Mexico. Although that area is suspect, such a short time there each year alone would not account for its .911 ppm blood DDE level. The southward migration was slow but steady, and it spent no significant time in any other area upon which we could focus before reaching its wintering area in Guanajuato State, Mexico. Earthworm samples at that site were not implicated and, since we were unable to track the ibis’s northward movement we cannot suggest a possible source of contaminants.
- Ibis 41309 (Fig. 4) left Carson Lake in early July, then spent at least one month (and perhaps almost two) in the Imperial Valley before traveling into the Mexicali Valley to winter. This individual could have acquired a portion of its DDE burden in the Imperial Valley.
- Ibis 19973 (Fig. 5) spent at least one months in the Imperial Valley before crossing the border into the Mexicali Valley. Therefore, the source of DDE could have been both the Imperial and Mexicali Valleys.
- Ibis 20043 (Fig. 6) was already at its contaminated wintering site when the PTT “awoke” on 27 October, near the U.S. – Mexico border (again, Imperial – Mexicali Valleys)

Although none of our sentinel ibis wintered in the Imperial Valley, given the area’s topography, agricultural history, and use by ibis, the Imperial Valley should be further investigated as a source for contaminants affecting the species.

We have identified, however, a definite source of DDE in the Mexicali Valley of Mexico (Table 2.), although the relative importance of the adjacent Imperial Valley in California to the total DDE exposure of the birds tracked to this region cannot be fully assessed from the data collected in this study. Avian species sharing that habitat with White-faced ibis during the February 2004 collecting trip are detailed in Table 3. A list of avian species observed during visits to all 12 defined ibis wintering sites comprises Table 4.

Although this constitutes our final report to Legacy on the contract, we are currently at work with our USGS collaborator, Dr. Charles J. Henny to publish our findings in a peer-reviewed journal. That article will be forwarded upon publication.

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Accrued Expenses

Quarterly dispersal reports were sent directly to the Corps of Engineers from the Office of Research Administration.

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Appendix A

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Dr. Mark R. Fuller (under Cooperative Agreement with the USGS Biological Resources Division)

Table 1. Timing of clutch completion and organochlorine (ppm, wet weight) residues in white-faced ibis eggs from various nesting segments at Carson Lake, Nevada, 1985, 1986, 1996 and 2000.

	Clutch completion			DDE ppm			Occurrence[a]						
Year	**Mean date**	**Range**	**N**	**Geo. Mean**	**High**	**DDE >4ppm**	**DDT**	**Dieldrin**	**HE**	**Chlordane[b]**	**Toxaphene**	**HCB**	**Endrin**
1985[c]	23 Apr	19-25 Apr	40	3.43	21	25 (63%)	7 (18%)	25 (63%)	0	0	1 (3%)	NA	6 (15%)
1985[c]	21 May	20-23 May	20	1.87	9	6 (30%)	4 (20%)	4 (20%)	1 (5%)	0	0	NA	4 (20%)
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%)
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%)
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%)
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%)
1996[c]	7 May	5-11 May	20	2.66	12	9 (45%)	12 (60%)	0	0	1 (5%)	NA	2 (10%)	0
2000[d]	29 Apr	26 Apr-1 May	10	3.63	8	6 (60%)	0	3 (30%)	0	0	0	0	0

NA = not analyzed, HE = heptachlor epoxide, HCB = hexachlorobenzene.
[a]Incidence of contaminants in eggs $\geq$ 0.10 ppm (the detection limit for 1985-86) for comparative purposes, but the detection limit was actually 0.01 ppm in 1996 and 2000.
[b]Includes oxychlordane, *trans*-nonachlor, and *cis*-nonachlor.
[c]Adapted from Henny (1997).
[d]Eggs in 2000 samples with > 0.01 ppm: HCB (3), dieldrin (8), endrin (8), o,p'-DDD (5), p,p'-DDD (6).

Table 2

DDE in blood plasma of adult male white-faced ibis sampled at Carson Lake, Nevada in 2000 and 2003, and DDE in earthworms collected on their wintering grounds

Wintering Grounds			DDE (wet weight)	
bird ID	general locale	Latitude / Longitude (decimal degrees, WGS 84)	blood plasma (ppm)	earthworms (mean ppb ± SE, N)
41305	no data	no data	0.990	no data
41308	Guanajuato, MX	21.0370N / 101.7440W	0.911	11.80 ± 2.52 (5)
41306	no data	no data	0.744	no data
19973	Mexicali south, MX	32.1105N / 115.1867W	0.667	269.63 ± 26.74 (5)
20043	Mexicali north, MX	32.5761N / 115.4376W	0.667	197.80 ± 45.91 (5)
41309	Mexicali central, MX	32.5103N / 115.2002W	0.623	339.87 ± 77.07 (5)
19945	Yuba City, CA	39.2599N / 121.5568W	0.380	35.65 ± 17.85 (3)
41311	no data	no data	0.266	no data
41310	Norco, CA	33.9480N / 117.5720W	0.155	25.31 ± 12.31 (4)
41303	no data	no data	0.154	no data
19978	Bakersfield, CA	35.9347N / 119.3981W	0.116	20.18 ± 3.66 (5)
41307	no data	no data	0.076	no data
20036	Guadalajara, MX	20.6023N / 103.2683W	0.063	no data
41304	Princeton, CA	39.3350N / 121.9250W	0.048	26.33 ± 12.90 (5)
19962	Gustine, CA	37.2370N / 120.9341W	0.028	5.73 ± 3.76 (7)
20059	Los Banos, CA	37.1436N / 120.8432W	0.025	15.07 ± 5.99 (5)
41302	Sinaloa, MX	23.9420N / 106.9730W	0.011	6.27 ± 3.71 (3)
19955	no data	no data	<0.002	no data
19957	no data	no data	<0.002	no data
20024	no data	no data	<0.002	no data

Table 3

Avian species observed at white-faced ibis wintering sites
with high earthworm DDE levels

Common Name	Scientific Name
Black-necked stilt	*Himantopus mexicanus*
Brown-headed cowbird	*Molothrus ater*
Cattle egret	*Bubulcus ibis*
Gambel's quail	*Callipepla gambelli*
Great egret	*Casmerodius albus*
Great-tailed grackle	*Quiscalus mexicanus*
Kildeer	*Charadius vociferus*
Mourning dove	*Zenaida macroura*
Northern mockingbird	*Mimus polyglottos*
Red-winged blackbird	*Agelaius phoeniceus*
Snowy egret	*Egretta thula*
Tree swallow	*Tachycineta bicolor*
Vermilion flycatcher	*Pyrocephalus rubinus*

Table 4
List of other avian species observed during visits to wintering sites
of 12 White-faced ibis captured at Carson Lake, Nevada in 2000 and 2003

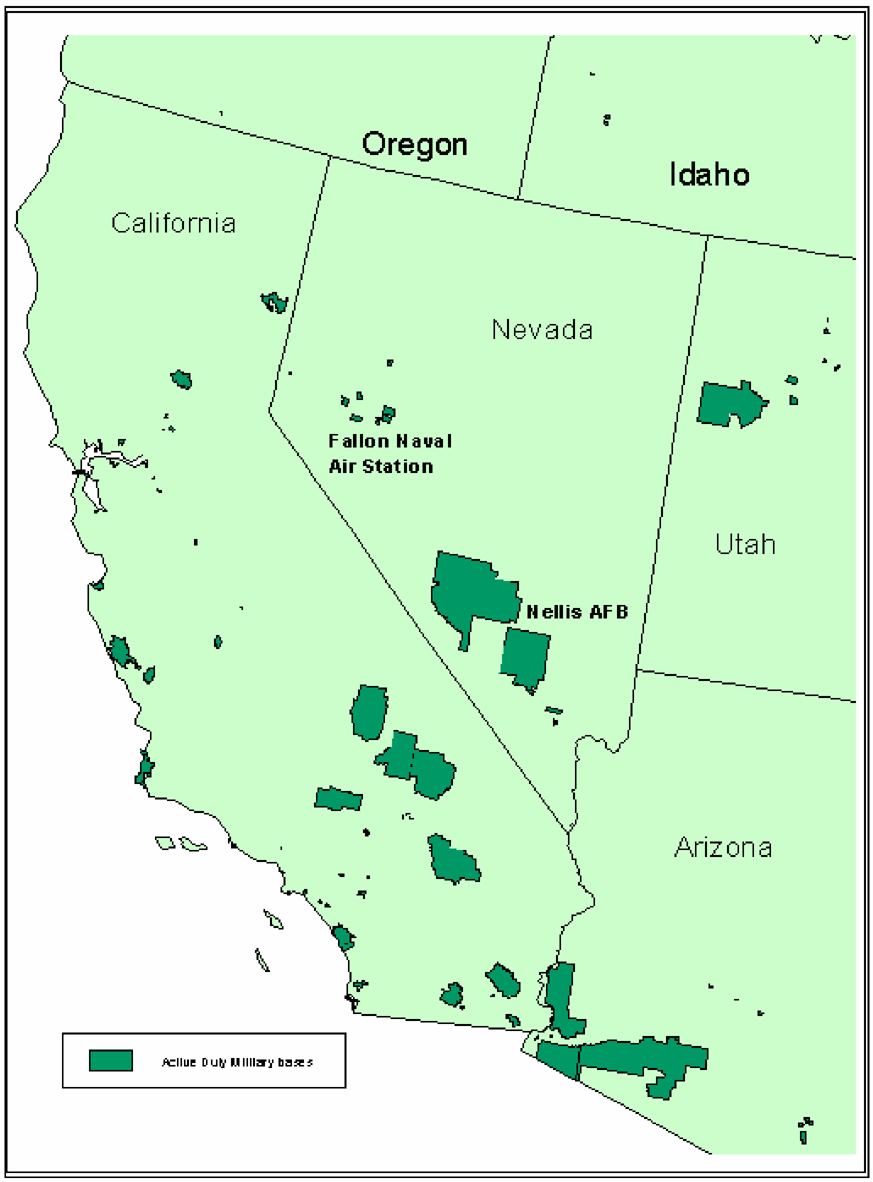
Common Name	Scientific Name
American avocet	*Recurvirostra americana*
American coot	*Fulica americana*
American coot	*Fulica americana*
American crow	*Corvus brachyrhynchos*
American kestrel	*Falco sparverius*
American white pelican	*Pelecanus erythrorhynchos*
Barn swallow	*Hirundo rustica*
Belted kingfisher	*Ceryle alción*
Black vulture	*Coragyps atratus*
Black-crowned night-heron	*Nycticorax nycticorax*
Black-necked stilt	*Himantopus mexicanus*
Black-shouldered kite	*Elanus caeruleus*
Blue-gray gnatcatcher	*Polioptila caerulea*
Blue-winged teal	*Anas discors*
Brewer's blackbird	*Euphagus cyanocephalus*
Bronzed cowbird	*Molothrus Aeneus*
Brown towhee	*Pipilo fuscus*
Brown-headed cowbird	*Molothrus ater*
California gull	*Larus californicus*
Canada goose	*Branta canadensis*
Cassin's kingbird	*Tyrannus vociferans*
Cattle egret	*Bubulcus ibis*
Cinnamon teal	*Anas cyanoptera*
Common ground-dove	*Columbina passerina*
Common moorhen	*Gallinula chloropus*
Common raven	*Corvus corax*
Common snipe	*Gallinago gallinago*
Cooper's hawk	*Accipiter cooperii*
Crested caracara	*Polyborus plancus*
Curve-billed thrasher	*Toxostoma curvirostre*
European starling	*Sturnus vulgaris*
Gambel's quail	*Callipepla gambelli*
Golden-fronted woodpecker	*Melanerpes aurifrons*
Great blue heron	*Ardea herodias*
Great egret	*Casmerodius albus*
Great kiskadee	*Pitangus sulphuratus*
Great-tailed grackle	*Quiscalus mexicanus*
Green heron	*Butorides virescens*
Green kingfisher	*Chloroceryle americana*
Groove-billed ani	*Crotophaga sulcirostris*
House finch	*Carpodacus mexicanus*
House sparrow	*Passer domesticus*
Inca dove	*Columina inca*
Kildeer	*Charadius vociferus*
Lesser yellowlegs	*Tringa flavipes*
Little blue heron	*Egretta caerulea*
Loggerhead shrike	*Lanius ludovicianus*
Long-billed curlew	*Numenius americanus*
Mallard	*Anas platyrhynchos*

Mourning dove	*Zenaida macroura*
Neotropic cormorant	*Phalacrocorax brasilianus*
Northern flicker	*Colaptes auratus*
Northern harrier	*Circus cyaneus*
Northern jacana	*Jacana espinosa*
Northern mockingbird	*Mimus polyglottos*
Northern rough-winged swallow	*Stelgidopteryx serripenis*
Northern shoveler	*Anas clypeata*
Pie-billed grebe	*Podilymbus podiceps*
Pintail	*Anas acuta*
Prairie falcon	*Falco mexicanus*
Purple gallinule	*Porphyrula martinica*
Red-shouldered hawk	*Buteo lineatus*
Red-tailed hawk	*Buteo jamaicensis*
Red-winged blackbird	*Agelaius phoeniceus*
Ring-billed gull	*Larus delawarensis*
Rock dove	*Columba livia*
Roseate spoonbill	*Ajaia ajaja*
Sandhill crane	*Grus canadensis*
Sandpiper (unidentified)	*Calidris sp.*
Snow goose	*Chen caerulescens*
Snowy egret	*Egretta thula*
Spotted sandpiper	*Actitis macularia*
Tree swallow	*Tachycineta bicolor*
Tropical kingbird	*Tyrannus melancholicus*
Tundra swan	*Cygnus columbanius*
Turkey vulture	*Cathartes aura*
Varied bunting	*Passerina versicolor*
Vermilion flycatcher	*Pyrocephalus rubinus*
Violet-green swallow	*Tachycineta thalassina*
Western kingbird	*Tyrannus verticalis*
Western meadowlark	*Sturnella neglecta*
White ibis	*Eudocimus albus*
White-winged dove	*Zenaida asiática*
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*
Yellow-rumped warbler	*Dendroida coronata*

Table 4 (cont.)

Figure 1

Department of Defense land in the Western U.S.
Data obtained from the Corps of Engineers



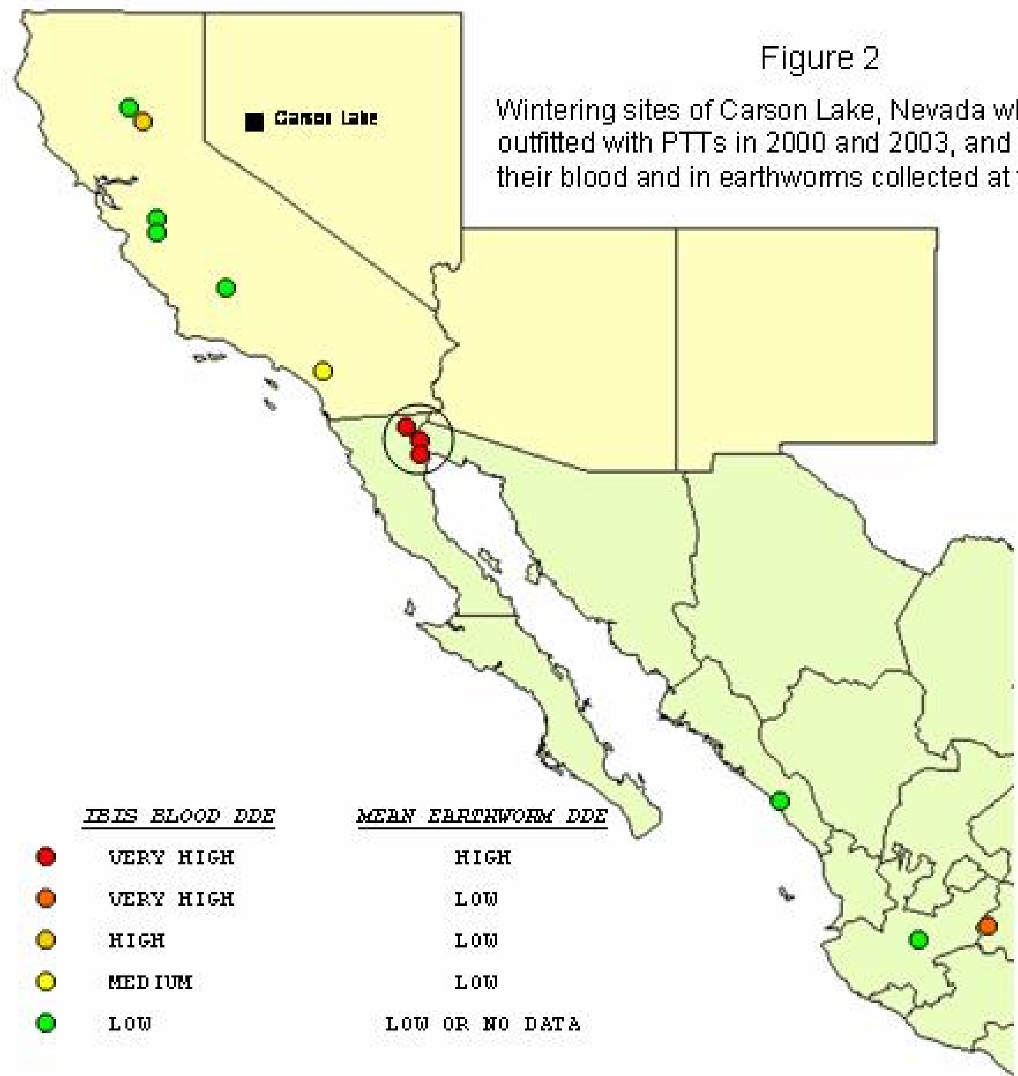


Figure 2

Wintering sites of Carson Lake, Nevada white-faced ibis outfitted with PTTs in 2000 and 2003, and DDE levels in their blood and in earthworms collected at those sites.

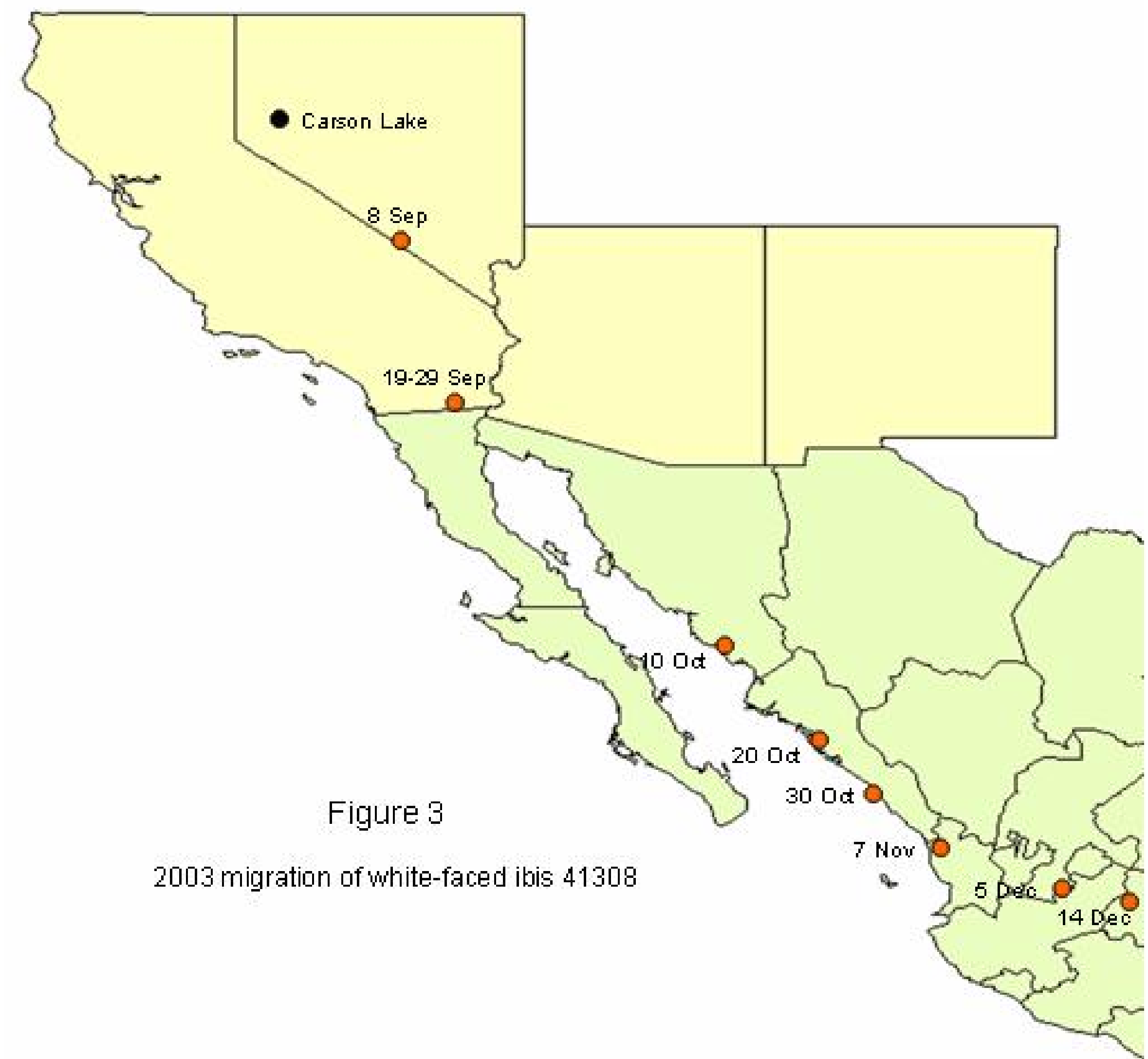


Figure 3

2003 migration of white-faced ibis 41308

Figure 4

2003 migration of white-faced ibis 41309

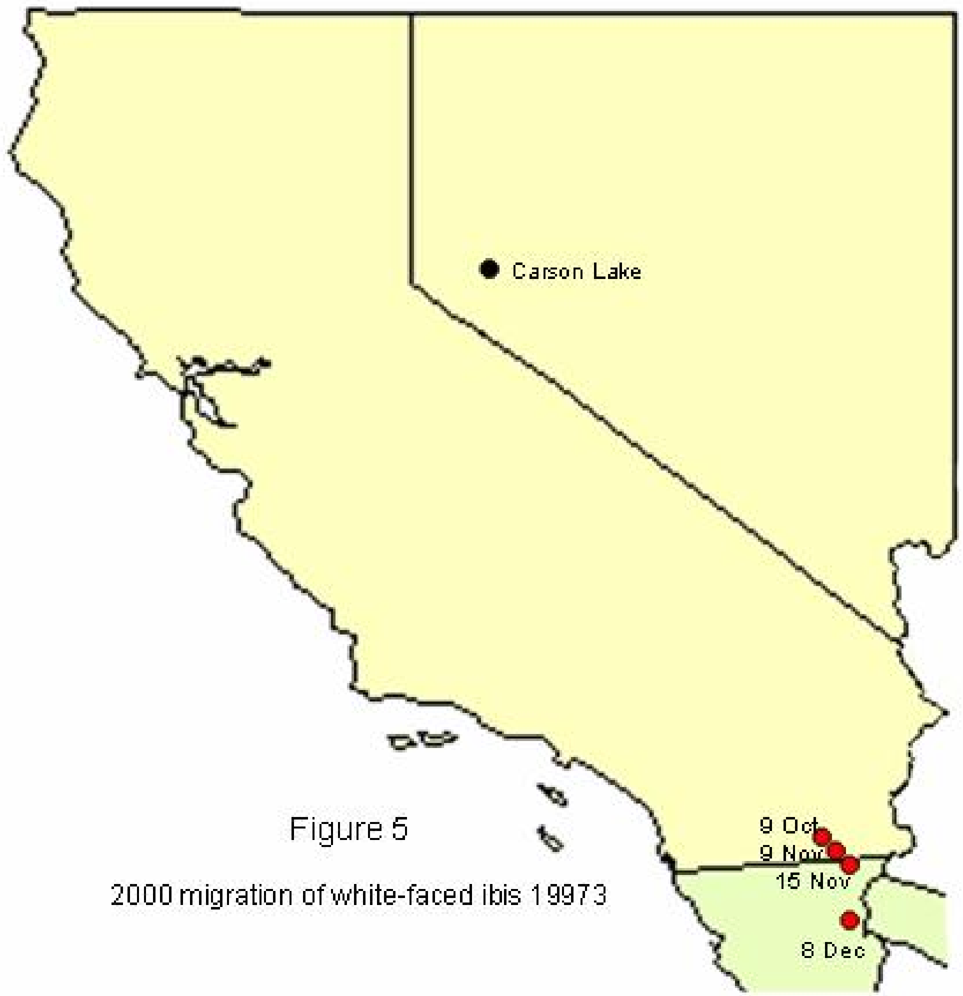


Figure 5

2000 migration of white-faced ibis 19973

Figure 6

2000 migration of white-faced ibis 20043