

DDE Contamination and Population Parameters of Bald Eagles *Haliaeetus leucocephalus* in California and Arizona, USA

J. Mark Jenkins, Ronald M. Jurek, David K. Garcelon,
Robert Mesta, W. Grainger Hunt, Ronald E. Jackman,
Daniel E. Driscoll & Robert W. Risebrough

ABSTRACT

Eggs laid by Bald Eagles reintroduced to Santa Catalina Island in southern California have continued to experience breakage in the field and embryonic death during artificial incubation; DDE levels have remained high since the first egg was laid in 1987. In northern California, however, the population is expanding with an annual increase of 6.7 %, a rate predicted by the population parameters measured in a 10-year study of 10 nesting pairs on the Pit River in Shasta County. The relatively isolated population of approximately 25 pairs in Arizona also maintains a high level of productivity, in the order of 0.9 young fledged per occupied nest. This paper summarizes the population and DDE residue data available at this time. DDE concentrations in excess of 3-5 ppm wet weight, previously determined to be the threshold level of effects on productivity in this species, were recorded in unhatched eggs from sites where mean productivity was high, suggesting a lower sensitivity to DDE than predicted from previous data.

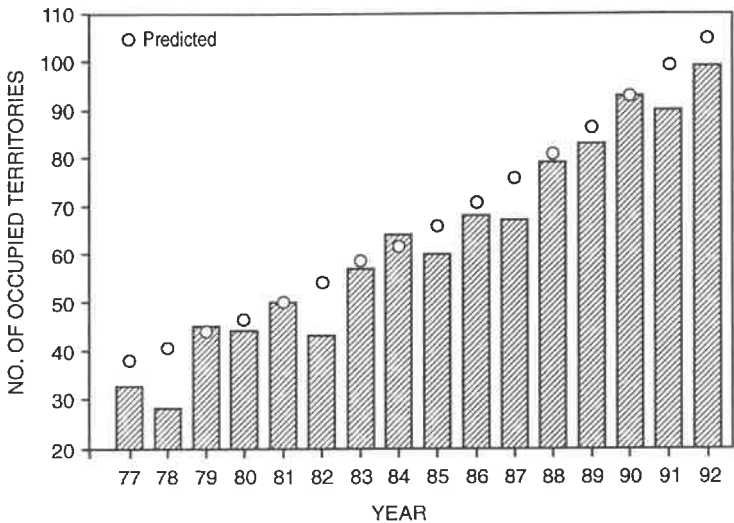
At the Third World Conference, Garcelon *et al.* (1989) described the reintroduction of Bald Eagles, *Haliaeetus leucocephalus*, to Santa Catalina Island in southern California. The species had been common on the southern California islands in the early years of the century, with a minimum population size of 24 pairs, but the last known breeding was recorded in 1949 (Kiff 1980). The excessively high contamination of the area by DDT compounds, derived from the wastes discharged by the world's largest manufacturer of DDT in Los Angeles, was considered the most plausible cause of this local extinction (Garcelon *et al.* 1989). The recovery of the productivity of local Brown Pelicans, *Pelecanus occidentalis*, from near zero in 1969-71 to near-normal levels in 1974, parallel with a steep decline of DDE residues in a principal prey species, the Northern Anchovy, *Engraulis mordax*, (Anderson *et al.* 1975) prompted the recovery program for the eagles. Unfortunately, the first egg laid by a reintroduced bird, in 1987, broke in the nest; DDE levels of 470 ppm in the yolk lipid (Garcelon *et al.* 1989) were several times higher than the threshold of

sensitivity to DDE previously determined by Wiemeyer *et al.* (1984) and Nisbet (1989). In this paper we summarize the breeding activities of the Santa Catalina eagles through 1991 and the population status of the species elsewhere in California and the adjacent state of Arizona, and present data on DDE residues in unhatched eggs throughout these areas.

Methods for the analysis of DDE have been described by Risebrough *et al.* (1986). Two eggs obtained in 1984 from Packer's Bay were analyzed in the laboratory of the California Department of Fish and Game. Unhatched eggs were collected toward or after the end of the breeding season and preserved frozen or refrigerated until analysis. Wet weights of the samples consisting of yolk lipids were estimated from the mean lipid content of 11 eggs showing no visible embryonic development, $7.32\% \pm 1.13$ (SD). Wet weight concentrations (Table 1) were not corrected for water loss; percent moisture is included among the data of Table 1.

In California, the breeding population has been monitored annually since 1970 by the California Department of Fish and Game in cooperation with other agencies and private individuals. Current procedures include a request that participants check each territory three times during the breeding season to determine occupancy, breeding activity, and productivity. The population has shown a continuing increase since the late 1970s (Figure 1; Jurek, 1990; Jurek, unpublished). Mean productivity, young fledged per active nest, in 1977-91 was 1.01.

Figure 1. Occupied territories of Bald Eagles in California, 1977-1992. Circles show predicted number of territories extrapolated from 1990 based on population parameters measured on the Pit River. Details in text.



Population parameters of 10 pairs breeding along the Pit River in Shasta County have been determined by Jenkins (this volume): adult survivorship, 94.6%; first-year survival, 76.9%; productivity, 0.81 young/occupied site. These parameters predict a yearly increase of 6.7 %. Application of this rate of yearly increase to the 1990 value of the breeding population yields a curve that closely matches the observed population increase in northern California in the 1980s (Figure 1). In the northern California population as a whole, survivorship, shown to be more important than productivity in affecting population change (Jenkins, this volume), is therefore similar to that determined for the Pit River group.

Breeding in southern California was observed in 1989 and 1990 on Lake Cachuma in Santa Barbara County (1 and 2 young fledged) and in 1990 on Lake Arrowhead east of Los Angeles (unsuccessful).

Table 1. Productivity of Bald Eagles in Arizona, northern California, and Santa Catalina Island in territories where unhatched or broken eggs were obtained for organochlorine analyses; DDE, parts per million.

Site	Year	Fledged	DDE lipid	DDE wet	Est. Prod.	Comments
ARIZONA						
Cedar Basin	1986	0				
	1987	0				
	1988	0	31	2.3	0.0	No visible development;
	1989	0				77.8% H ₂ O
	1990	0				
Chino	1985	2				No visible development;
	1986	0(2)	110	8.9	1.0	64.3% H ₂ O; two young
	1987	--				fostered into nest; new female in 1987.
McDowell	1986	2				
	1987	1				
	1988	0	94	8.0	1.25	No visible development;
	1989	2				77.1% H ₂ O
Cliff	1988	2				
	1989	0	120	7.7	0.67	No visible development;
	1990	0				78.0% H ₂ O
Horseshoe	1987	3				
	1988	1				
	1989	0	74	3.4	1.50	No visible development;
	1990	2				78.5% H ₂ O
Alamo	1988	1				
	1989	1	130	5.3	1.33	Embryo, 1/3 development;
	1990	2				80.0% H ₂ O
Horse Mesa	1985	0				
	1986	2	100	4.7	1.33	Embryo, 3/4 developed
	1987	2		(est.)		65.9% H ₂ O; 5.9% lipid
SANTA CATALINA IS.						
Twin Rocks Female „Chator“	1987	0	470			One egg, broke in nest;
				25 (est)	0.0	yolk remnants analyzed
	1989	--	210			Early embryo died, artificial incubation
Seal Rocks Female „Shasta“	1988	0	740			One egg, broke in nest;
				67 (est)	0.0	yolk remnants analyzed
	1990	--	1,100			Early embryo died, artificial incubation
Pinnacle Rock Female „Bray“	1991	--	600	44 (est)	0.0	Early embryo died, artificial incubation

Site	Year	Fledged	DDE lipid	DDE wet	Est. Prod.	Comments
Lands End Female „Wray“	1991	(1)				Two eggs laid, artificial incubation; one hatched, second died at pipping.
NORTHERN CALIFORNIA						
Pit River, Shasta Co						
Dusty	1985	0				
	1986	0	41	2.5		No development; 81.6 %H ₂ O
	1987	0				
	1988	0	26	2.5	0.6	No development; 76.0 %H ₂ O
	1989	2				
	1990	2				
South Shore	1982	0				
	1983	0	120	--		Crushed egg
	1984	0				
	1985	--	61	4.7	0.0	3 eggs removed, artifical incubation, no development
	1986	0				
	1987	0				
North Shore	1982	0				
	1983	2				
	1984	0	150			Crushed egg
	1985	0				
	1986	--	53	4.1	0.25	2 eggs removed, artifical incub., 78.4% H ₂ O (mean); small embryos died
	1987	1				
	1988	0				
Pit 3	1988	2				
	1989	2				
	1990	0	26	1.3	1.0	2 large embryos, died near hatching after death of female; 83.6% H ₂ O
	1991	0				
Pit 6	1988	0				
	1989	0	24	0.50	0.25	Embryo near hatching
	1990	1				
	1991	0				
O'Brien, Shasta Co.	1984	1				
	1985	0				
	1986	--	280 (est)	8	1.0	Artificially incubated, chick near hatch; 5.5% lipid, 79.7% H ₂ O
	1987	2				
	1988	1				

Site	Year	Fledged	DDE lipid	DDE wet	Est. Prod.	Comments
Packer's Bay, Shasta Co.	1982,83	1				
	1984	0	--	9.5	0.4	Means of 2 eggs; analysis CDFG, small embryos
	1985,86	0				
	1987	0				
	1988	2				
	1989	0				
	1990	1				
	1991	0	19	1.3	0.5	Embryo 1/2 developed; 80.3% H ₂ O
Hirz Bay, Shasta Co.	1992	0				
	1982	1				
	1983	0				
	1984	0	175	10	0.8	No develop., 82.7% H ₂ O
	1985	1				
Lake Pillsbury, Lake Co.	1986	2				
	1982	2				
	1983	0				
	1984	0	90	5.6	1.0	No develop., 80.0% H ₂ O
	1985	2				
Mountain Meadows West, Lassen Co.	1986	1				
	1984,85	NO				
	1986	0	34	2.5	0.67	No develop., 77.6% H ₂ O
	1987	2				
Cool Springs, Plumas Co.	1988	0				
	1984	2				
	1985	1				
	1986	0	110	8.5	1.4	No develop., 79.8% H ₂ O
	1987	2				
Rocky Point, Lake Almanor	1988	2				
	1984,85	0				
	1986	0	300	22	0.0	No develop., 66.3% H ₂ O
	1987	NO	(est)			12.3% lipid
Mud Creek Rim, Lake Almanor	1988	0				
	1984	0	75	2.6	0.67	Early embryo; 83.7% H ₂ O
	1985	2				
	1986	0				

NO: not occupied

Among the northern California sites from which one or more unhatched eggs were obtained, two had zero productivity over the period of observation (Table 1). The female of South Shore was found dead in April 1992 with injuries probably inflicted by another eagle; a stricture in the lower oviduct accounted for the reproductive failures (National Wildlife Health Research Center, Madison, Wisconsin). The egg from the other site, Rocky Point, contained 300 ppm DDE in the lipid, estimated from the mean lipid determination to be equivalent to about 22 ppm wet weight. This is in the range where the data presented by Wiemeyer *et al.* (1984) would predict a very low level of reproductive success. Eggs from 5 of the remaining 12 sites (2 values from Packer's Bay) had DDE levels above 5 ppm, in the higher range of the estimated threshold interval, suggesting potential effects on productivity. Productivity of the more contaminated group, however, was

higher (0.92 vs 0.56).

The Arizona population of approximately 25 pairs appears to be stable; reported productivities have ranged from 0.80 young/occupied territory in 1975-81, 1.13 in 1982-86, to 0.87, 1.04, and 0.52 in 1987-89 (Forbis 1988; Grubb *et al.* 1990; Hunt *et al.* 1992). A review of all of the available data, however, has shown that productivity and nest success rates have remained stable over the past two decades at levels comparable to those reported in other populations in North America considered healthy. Overall, the mean young per occupied site was 0.9 eaglets; nest success averaged 57%. A nest occupancy rate of 85% was 14% higher than the average for other populations as reported by Stalmaster (1987); the 15% nestling mortality rate in Arizona equals that in other populations (Hunt *et al.* 1992).

Unhatched eggs were obtained in 1986-89. Two of the sites had been sampled previously by Grubb *et al.* (1990). Two eggs from Horseshoe contained a mean DDE concentration of 8 ppm in 1977; the 1989 egg contained 3.4 ppm. Horse Mesa eggs contained 4.4 and 4.7 ppm in 1983 and 1986, respectively (Grubb *et al.* 1990; Table 1). Geometric mean DDE concentration in the earlier eggs was 3.3 ppm; 4 of the 7 eggs from the later collection contained DDE levels above 5 ppm; correction for water loss would decrease these values by no more than 20% (Table 1); corrected values would remain above 5 ppm. These higher values of DDE do not appear to be associated with depressed productivity (Table 1).

In contrast, all but one of the eggs laid by the reintroduced birds on Santa Catalina Island in 1987-1991 broke in the nest or the embryo died during artificial incubation (Table 1). After the second egg laid, by female 'Shasta' in 1988, broke in the nest, the decision was made to remove eggs for artificial incubation at the Predatory Bird Research Group facilities in Santa Cruz. Female 'Chator', who laid the 1987 egg, produced 2 eggs in 1989: the first disappeared within 48 hours; the embryo of the second died at an early stage, the egg showing an abnormally high rate of water loss (J. Linthicum and B.J. Walton, unpublished). High water loss and early embryonic death also occurred in the egg produced by 'Shasta' in 1990. In 1991, three eggs were produced by two pairs; one of these hatched after artificial incubation and the young bird was fledged in the wild. All of the eggs analyzed contained exceptionally high levels of DDE (Table 1). Management of this population by artificial incubation and/or the importation of healthy eggs from other areas will evidently be necessary for years to come.

The present data set from California/Arizona therefore supports the conclusions reached from the set compiled by Wiemeyer *et al.* (1984) from eggs laid in 1969-1979, mostly in eastern North America, that depressed productivity is associated with higher levels of DDE; the apparent threshold of sensitivity appears, however, to be higher in California/Arizona. This question is explored in the companion paper by Nisbet and Risebrough (this volume).

ACKNOWLEDGEMENTS

Research was supported by the Pacific Gas and Electric Company, the California Department of Fish & Game, the Catalina Island Conservancy, the U.S. Bureau of Reclamation, and the Bodega Bay Institute.

J. Mark Jenkins
Technical and Ecological Services
Pacific Gas and Electric Company
3400 Crow Canyon Road
San Ramon, CA 94583, USA

David K. Garcelon
Institute for Wildlife Studies
P.O. Box 127
Arcata, CA 95521, USA

W. Grainger Hunt, Ronald E. Jackman
& Daniel E. Driscoll
BioSystems Analysis, Inc.
303 Potrero St., Suite 29-203
Santa Cruz, CA 95060

Ronald M. Jurek
California Department of Fish and Game
1416 Ninth Street
Sacramento CA 95814

Robert W. Risebrough
The Bodega Bay Institute
2711 Piedmont Avenue
Berkeley, CA 94705, USA

Robert Mesta
U.S. Fish and Wildlife Service
Ventura Field Office
2140 Eastman Avenue, Suite 100
Ventura, CA 93003, USA