Meyburg, B.-U. & R. D. Chancellor eds. 1989
Raptors in the Modern World
WWGBP: Berlin, London & Paris

Accumulation of DDE by Bald Eagles *Haliaeetus leucocephalus* Reintroduced to Santa Catalina Island in Southern California

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Records of 19th century naturalists indicate that the Bald Eagle, *Haliaeetus leucocephalus*, was once a common species in southern California. On the mainland, persecution and encroachment upon habitat brought its local extinction, and there are only a few breeding records after the turn of the century (Kiff 1980). Although the eagles were persecuted by sheep ranchers and frequently shot by occasional visitors, the species remained fairly common on the largely uninhabited Channel Islands throughout the earlier years of the century. By the end of the 1950s, however, the species was gone. Kiff (1980) reviewed all the available literature, the unpublished notes of naturalists, museum collections of eggs and specimens, and interviewed long-time residents of the islands and visitors to the islands during the years when eagles still occurred. He concluded that the minimum size of the breeding population was 24 pairs; the last known nesting was in 1949.

The marine environment of southern California has experienced the highest levels of DDE contamination ever recorded in coastal zones, the legacy of the wastes discharged by the world's largest manufacturer of DDT. Unknown to the environmental scientific community until recently, however, was that the acid wastes of the company were discharged at sea between Los Angeles and Santa Catalina Island from 1947 until 1961; yearly discharges were estimated to be in the order of 20-40 tonnes (Risebrough 1987). The "caustic" wastes of the manufacturing process continued to be discharged into the local wastewater system, introducing in the order of 200-300 kg of DDT compounds into the sea per day, until discharge was stopped in 1970 (Carry & Redner 1970).

The Bald Eagle is one of the species most sensitive to DDE contamination. Analyses of the relationships between productivity and DDE concentrations in the eggs by Wiemeyer *et al.* (1984) and by Nisbet (this volume) have indicated that levels of 3-5 ppm are associated with depressed productivity and that there is virtually no reproduction when DDE levels exceed 15 ppm. In contrast, productivity of Peregrine Falcons, *Falco peregrinus*, is not depressed until DDE levels exceed 15 ppm (Peakall *et al.* 1975; Fyfe *et al.* 1988). The direct introduction of DDT compounds into the marine environment after 1946, under conditions in which almost all would be incorporated directly into food webs and resulting in high concentrations in the eagles, can now be considered as the cause of the local disappearance of the species.

Use of mussels, *Mytilus californianus*, as an indicator species for local levels of contamination by DDE and other organochlorines indicated that environmental levels of DDE declined rapidly in

the early 1970s following ending of the discharge (Risebrough *et al.* 1980). DDE levels in the local Brown Pelicans, *Pelecanus occidentalis*, which had experienced massive eggshell thinning and virtually no reproduction in the late 1960s and early 1970s, and in a principal prey species, the Northern Anchovy, *Engraulis mordax*, also declined rapidly; reproduction returned to normal (Anderson *et al.* 1975).

The success of the Brown Pelicans, which like the Bald Eagles are also very sensitive to DDE contamination, with the "cleaning" of the local environment which physically has remained largely unchanged, suggested that it would be appropriate to re-introduce Bald Eagles to the Channel Islands. A programme was begun in 1980, when 6 chicks from donor nests in Washington at 7-8 weeks of age were brought to Santa Catalina Island. They were placed in cages on artificial nest platforms, and were fed principally on feral goats, *Capra hircus*, feral pigs, *Sus scrofa*, ground squirrels (*Spermophilus beecheyi*), and both fresh-water and marine fish. After leaving the nest platforms they continued to feed largely on carcasses of feral pigs and goats which were provided for them.

In following years the number of birds and their sites of origin were: 1981, 5 from Washington and one from northern California; 1982, 3 from Washington and one from northern California; 1984, 4 from northern California; 1985, 5 from northern California; 1986, 8 from British Columbia.

After the eagles fledged, their activities were monitored with the aid of telemetry equipment in order to determine habitat use, social interactions and mortality. With maturity, they began to feed upon marine fish and birds. To determine the accumulation of organochlorines from the prey base, eagles were periodically trapped using rocket nets, padded leg-hold traps, or floating noose nets. One bird was recovered from a trapping station set up on the mainland for California Condors, *Gymnogyps californianus*. Samples of whole blood were drawn and frozen for later analysis. The carcass of an adult found dead was shipped to the Patuxent Analytical Control Facility of the U. S. Fish and Wildlife Service for residue analysis. The first nesting was recorded in 1987, but the egg(s) broke during incubation. An egg fragment with attached yolk was recovered for analysis.

Three species of gulls, the California Gull, *Larus californicus*, the Heermann's Gull, *L. heermanni*, and the Western Gull, *L. occidentalis*, were collected on the coast of Santa Catalina Island. Breast muscle tissue was analyzed for DDE in the laboratory of the California Department of Fish and Game.

Kelp Bass, *Paralabrax clathratus*, were obtained by spear-fishing from north-eastern and south-western coastal waters. Black Surf Perch were also obtained from the south-west site. The fish, blood and egg yolk were analysed at University of California facilities with methods described by Risebrough (1987).

DDE levels in blood were highly variable, but with the lowest concentrations occurring in one-year birds, and the highest concentration, 16 ppm, in a two-year bird (Table 1). The differences presumably reflect differences in the relative amounts of carrion consumed, assumed to have lower levels of organochlorine contaminants than fish. Ratios of DDE to the PCBs and other organochlorines are also variable, reflecting the contamination patterns in the several food sources (Risebrough, unpubl.).

Since the lipid content of whole, fresh eggs is in the order of 5% (Risebrough, unpubl.), a level of 5 ppm wet weight in an egg, a level found to be in the critical range by Wiemeyer *et al.* (1984) and Nisbet (this volume), would be equivalent to a lipid concentration of 100 ppm. The concentrations recorded in the yolk lipid and in the adult carcass exceed this level by a wide margin (Table 1), indicating that local levels of DDE may be too high for successful reproduction without artificial manipulation.

Wiemeyer *et al.* (1978) determined levels of DDE and other organochlorines in fish and in Herring Gulls, *L. argentatus*, from areas of Maine where Bald Eagles were experiencing low productivity and the population was declining. Productivity over 1962-1970 was only 0.35 young per active nest, whereas a level of 0.70 was considered necessary to maintain population stability (Sprunt *et al.* 1973). Levels in fish in 1966, excluding eels, were in the general order of 0.1-0.5 ppm wet weight, generally higher than those we recorded in Kelp Bass and Surf Perch (Table 1). Because of a higher lipid content, levels in eels were higher, in the order of 1 ppm. DDE levels in carcasses of 5 Herring Gulls ranged from 1.7 to 5.9 ppm wet weight, equivalent to those we report here in the three species of gulls from Santa Catalina Island (Table 1). Although the Maine eagles were feeding principally on fish and eels, occasional ducks and gulls were recorded among the prey items (Wie-

meyer *et al.* 1984). On Santa Catalina Island, it would appear that the occasional birds consumed by adult eagles are responsible for the higher levels of DDE recorded in the yolk lipid and in the adult carcass.

On the coast of Central California, to the north of the Channel Islands, the breeding density of Peregrine Falcons has returned to that of the pre-DDT era through a programme of active manipulation by the Santa Cruz Predatory Bird Research Group. Natural productivity is still very low; DDE levels remain very high and shell thinning is severe. Placing of captive-reared young in nest sites has ensured normal levels of productivity (B. J. Walton, pers. comm.).

A comparable programme with the Bald Eagles on the Channel Islands, replacing unhealthy eggs with viable eggs or young from other areas, would ensure maintenance and a continuing growth of the local population until environmental levels of DDE permit natural reproduction.

TABLE 1. DDE concentrations, parts per million, in blood, yolk of a broken egg, and an adult carcass of Bald Eagles from Santa Catalina Island, and in selected prey species.

Species	#, N	Years after release	Tissue	ppm	basis	
Bald Eagle	1	1	Blood	7.4	dry	
	2	1	"	0.95	"	
	3	1	"	3.3	"	
	4	1	"	0.048	"	
	5	1	"	0.014	"	
	6	1	"	0.027	"	
	6	2	"	0.37	"	
	7	2	"	16	"	
	8	2	"	0.20	"	Recovered from mainland
	9	5+	yolk	470	lipid	
	10	5+	carcass	45	wet	980 ppm lipid basis
				120	dry	
California Gull	N=8	--	muscle	2.6	wet	Arith. mean, S.D. 4.6
Heermann's Gull	N=7	--	"	3.2	wet	Arith. mean, S.D. 3.1
Western Gull	N=7	--	"	2.3	wet	Arith. mean, S.D. 2.0
Kelp Bass						
NE coast	N=6	--	"	0.063	wet	Geom. mean, one interval S.D. 0.015-0.28
SW coast	N=7	--	"	0.015	wet	Geom. mean, one interval S.D. 0.005-0.41
Black Surf Perch, SW coast	N=11	--	"	0.003	wet	Geom. mean, one interval S.D. 0.001-.006

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