

Relationship of DDE to Productivity of Bald Eagles *Haliaeetus leucocephalus* in California and Arizona, USA

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ABSTRACT

Analysis of the relationships between the DDE concentrations in unhatched eggs of Bald Eagles in California/Arizona in 1984-1991 and estimated productivities showed a significant S-shaped dose response. Productivity was not affected by DDE concentrations below 9-12 ppm wet weight, but declined sharply above 12 ppm. This critical level of sensitivity to DDE is higher than that (3.8 ppm) found in an earlier analysis of Bald Eagles from other parts of the USA in 1969-79, but statistical significance could not be shown with the available sample size. The difference, however, suggests that an additional factor may have been operating in the earlier period.

INTRODUCTION

Wiemeyer *et al.* (1984) and Nisbet (1989) analyzed the relationships between productivity in Bald Eagles *Haliaeetus leucocephalus* and organochlorine contaminants, using data compiled by Wiemeyer *et al.* (1984) for eight regions of North America between 1969 and 1979. They found that reduced productivity in this species was most closely associated with egg residues of DDE. However, they were unable to exclude the possibility that other contaminants may have contributed to reproductive failure in this species, in part because of intercorrelations among the residue levels of the various contaminants.

One approach to resolving this issue is to examine other sets of data on the same species. By analyzing data from other geographical areas or later periods, it may be possible to find data sets with different patterns of residue levels of the various contaminants. This paper reports on productivity and egg residue levels of DDE in Bald Eagles nesting in California and Arizona between 1984 and 1991. The specific hypothesis tested is whether the relationship between productivity and DDE in this area and in this time period is the same as that found in the data of Wiemeyer *et al.* 10-15 years earlier and in different parts of North America. If not, the difference will suggest that other factor(s) were operating in one or both of the populations.

MATERIALS AND METHODS

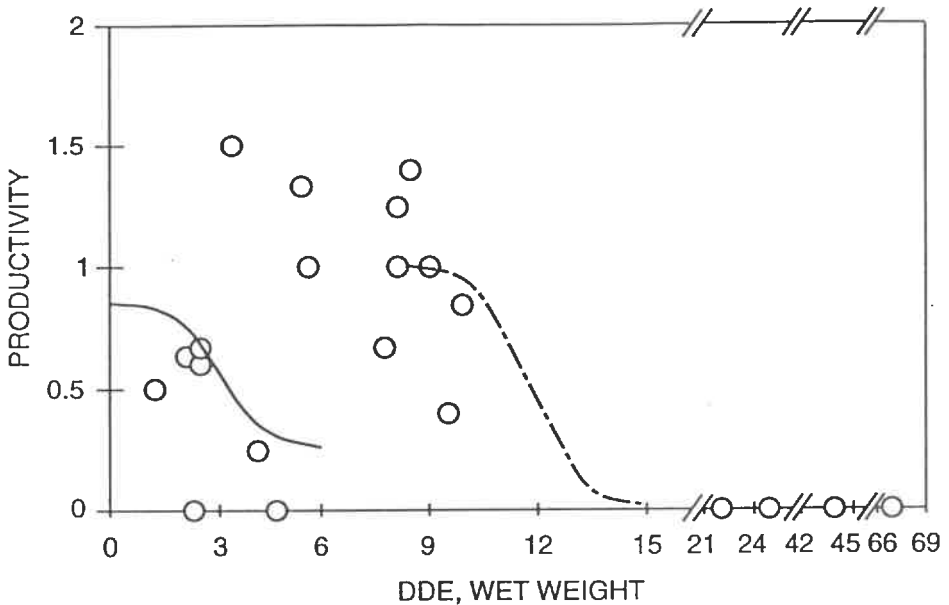
We used the data set compiled by Jenkins *et al.* (this volume). Included in Table 1 of that paper are all of the productivity data used to derive the estimate of mean productivity for each nesting area. The three critical samples from Santa Catalina Island were assigned productivity estimates of zero, since eggs either broke in the nest or embryos died during artificial incubation. When more than one egg was obtained from a site, DDE, water, and lipid contents were averaged. Samples from Horse Mesa, Pit 3 and Pit 6, containing advanced embryos or chicks near hatch, were not used in the final analysis. The two samples from Packer's Bay, separated by 7 years, were considered as two values. The O'Brien sample, a chick near hatch, contained 280 ppm DDE lipid weight, 15.4 ppm wet weight. Although lipid content was relatively high (5.5%), DDE was estimated conservatively as 8 ppm to account for changes during incubation. The Almanor egg contained 37 ppm wet weight, but water content was low. The estimated wet weight was derived from the mean percent lipid, 7.3 % (Jenkins *et al.*, this volume). No correction was made for water loss in the remaining samples; water content was greater than 75% in all but one, the egg from Chino. The sample selected consisted therefore of 6 territories in Arizona, 12 territories in northern California, and 3 on Santa Catalina Island (Figure 1).

We fitted the data to the linear regression model

$$P^k = a + b(1 + \text{DDE}^n/c^n)^{-1},$$

where P = mean productivity, DDE is the concentration of DDE in the sample egg, a and b are regression parameters to be determined, and k, c and n are parameters defining the S-shaped dose-response function. Values of k, c and n were explored systematically until the explained variance R^2 was maximized. This procedure is the same as that used by Nisbet (1989) for the 1969-79 data set; the parameter values obtained by Nisbet for this data set were $k = 1.4$, $c = 3.8$, $n = 20$. The resulting curve, shown in Figure 1, drops sharply in the DDE range around 3.8 ppm.

Figure 1. Productivity of Bald Eagles in California/Arizona in 1984-91 vs. the DDE concentrations in egg contents. Dashed line: California-Arizona data set of this paper; solid line: derived by Nisbet (1989) for data set of Wiemeyer *et al.* (1984).



RESULTS AND DISCUSSION

Our analysis of the 1984-91 California/Arizona data set fixed a value of $k = 1$; this parameter has the greatest influence on the predicted productivity at $DDE = 0$. The best fit to the regression model was obtained with $c = 12$, $n = 18$ ($R^2 = 0.362$, $P = 0.004$). Lower values of k increased values of R^2 . This result is consistent with earlier findings (Nisbet 1989) that reduced productivity in Bald Eagles is significantly associated with egg residues of DDE, and that the dose-response relationship is S-shaped (Figure 1).

Our curve for the 1984-91 data set has an inflection point at $DDE = 12$ ppm, whereas that for the 1969-79 set has an inflection point at $DDE = 3.8$ ppm. On the null hypothesis that there is no difference in distribution between the California/Arizona data and the 1969-79 data, there is an equal probability that the points corresponding to these eggs would fall above or below the 1969-79 regression line. Seven of the points fall below this line, 14 above (or have $DDE > 14$ ppm). The null hypothesis for this sample size can not be rejected ($P > 0.10$, chi-square test). A larger sample size would be needed to provide a critical test of the hypothesis.

The difference between the two critical values suggests that an additional factor (either independent of or correlated with DDE) contributed to reduced productivity in the 1969-79 data set. Possible candidates for such a factor include another contaminant (e.g., PCBs or oxychlordane), an interaction between DDE and another contaminant, or a residual effect of the birds' exposure to higher DDE levels in the years before 1969. Oxychlordane was the contaminant most strongly associated (after DDE) with reduced productivity in the 1969-79 data set (Nisbet 1989). However, data on oxychlordane levels, as well as of PCBs and the other organochlorines, in the California/Arizona eggs are not yet available. PCBs were highly correlated with DDE in the 1969-1979 data set (Wiemeyer *et al.*, 1984) such that a PCB effect, or a synergistic DDE-PCB effect, may not have been detectable. The residual effect hypothesis might be testable if data were available for an identifiable pair during a period of DDE decline.

In spite of our failure to demonstrate statistical significance, the data nevertheless provide support for a hypothesis that DDE was not the only contributor to the reproductive failures experienced by Bald Eagles in earlier years.

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