took into account the probe size both as a light source and a vignetting object. Where vignetting introduced an uncertainty about the amount of astigmatism present, a minimum estimate was taken. The maximum amount of astigmatism which can be present but not measurable due to vignetting is approximately 0.25 diopter at a distance from the camera of 1.5 m, and 0.5 diopter at 0.7 m.
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Productivity of Ospreys in Connecticut–Long Island Increases as DDE Residues Decline

Abstract. *Nesting success of ospreys (*Pandion haliaetus*) breeding in the Connecticut–Long Island area has increased since 1973 and is now approaching the levels recorded prior to the 1950's. Simultaneously, DDE and dieldrin residues have declined in unhatched eggs. Levels of polychorinated biphenyls have shown no changes over the period 1969 to 1976. The increase in productivity is attributed primarily to lower levels of DDE contamination. Detrimental effects in the past on ospreys in the Connecticut River estuary are attributed to local contamination with dieldrin.*

Ospreys (*Pandion haliaetus*) breeding in Connecticut and eastern Long Island (hereafter C-LI) declined rapidly in numbers in the late 1950's and throughout the 1960's, in association with abnormally low reproductive success (*1–4*). Earlier, between 1938 and 1942, Wilcox (*5*) had banded an average of 1.71 young per active nest (annual range 1.38 to 2.21) among a total of 100 nests on Gardiners Island, Long Island. In the early and mid-1960's, productivity fell to 0.07 to 0.4 young per active nest on Gardiners Island, in the Connecticut River estuary, and at Orient Point (*1, 3*). The productivity of these ospreys has since increased from about 0.5 fledged young per pair in 1969 to 1973 to 1.2 fledged young in 1976–77 (Fig. 1), approaching the range observed in 1938 to 1942. We now report that this increasse in reproductive success has coincided with a decrease in residues of DDE and dieldrin (*6*), and we provide further evidence for the conclusion that low reproductive success of ospreys is associated with residues of DDE in their eggs (*2, 4, 7–9*).

The major cause of low productivity of C-LI ospreys in the 1960's was failure of eggs to hatch, rather than failure of adults to breed (*1, 2*). Exchanges of eggs in 1968, 1969, and 1973 between nests in C-LI and Maryland, where hatching rates were substantially higher, showed that the factor (or factors) responsible for hatching failure were intrinsic to the egg and did not include abnormal parental behavior or human disturbance (*4, 10*).

Eggs from Connecticut that were used in transplant experiments or were collected unhatched in the period 1967 to 1970 had shells 15 to 20 percent thinner than the mean for eggs collected in the eastern United States prior to 1947 (*4, 7*). This degree of eggshell thinning approximates the critical level associated with hatching failure in other species (*7*). Shell thinning of osprey eggs, as in other species (*11, 12*), has been associated primarily with residues of DDE (*8*). Other chemical pollutants, however, including PCB's (*6*), dieldrin (*4, 8*), smaller quantities of other organochlorine compounds, and chemicals as yet unidentified (*13*), have been detected in osprey eggs from C-LI. The cause of the low productivity could not therefore be associated with certainty with any particular pollutant or with shell thinning per se.

We collected unhatched (*14*) osprey eggs from representative nests in C-LI between 1969 and 1976. Organochlorine and mercury residues were measured as described (*15*). Geometric mean concentrations of DDE declined fivefold between 1969 and 1976 and approximately threefold since 1973 (Fig. 1). This decline followed the decline in uses of DDT in the northeastern United States during the 1960's and the virtual cessation of DDT use in North America since 1972 (*12*). In spite of restrictions on uses of PCB's (*16*), their levels in osprey eggs have shown no significant changes between 1969 and 1976 (Fig. 1). Dieldrin has also declined significantly in the same period: geometric means, parts per million (ppm), dry weight, were 1.04, 1.05, 1.25, 0.95, and 0.78 in 1969 to 1973, and 0.25 in 1976 (sample sizes are the same as those shown in Fig. 1). This decline coincides with the cessation of use of aldrin (*6*) and dieldrin since 1974.

Table 1. Associations of osprey productivity with shell thickness and pollutant levels in sample eggs.

Miscellaneous	Young produced per active nest			Probability of difference	
	None	One	Two*	Analysis of variance	Kruskal-Wallis
Number of nests	41	14	13		
Mean shell thickness (μm)	411	436	442	.051	.054
Pollutant levels in unhatched eggs†					
DDE	113	59.6	29.1	$<10^{-8}$	$<10^{-9}$
PCB	144	130	83.8	0.027	0.025
Dieldrin	0.89	1.05	0.43	0.005	0.021
Mercury‡	0.25	0.18	0.22	0.621	0.728

*Includes one nest in which three young were raised. †Geometric means, parts per million, dry weight. There were significant associations between several of the pollutant variables. The correlation coefficient r between ln DDE and ln PCB was .531 ($P < .0001$); r between ln DDE and ln dieldrin was .432 ($P < .001$). Eggshell thickness was related to ln DDE by the regression equation: thickness = 501 − 18.2 (ln DDE), $F = 8.2$, $P < .01$. ‡N = 35, 10, 7, respectively.

0036-8075/78/1020-0333$00.50/0

Mean eggshell thickness increased during this period (from 412 ± 8 μm in 1970, $N = 23$, to 446 ± 19 μm in 1976, $N = 10$; mean ± standard error), but the difference was not statistically significant ($P > .05$, Mann-Whitney U test).

In each nest from which an unhatched egg was collected for analysis, the number of young raised to fledging was determined by periodic visits. Associations between the number of young raised, residues of the four pollutants identified in largest quantities, and eggshell thickness were examined by analysis of variance, the nonparametric Kruskal-Wallis test, and linear regression analysis (Table 1). There was a strong inverse association between productivity and levels of DDE in the sample eggs ($P < 10^{-8}$). Productivity was also significantly associated with levels of PCB's and dieldrin, and almost significantly associated with eggshell thickness, but these associations were much weaker than that with DDE. Within this sample PCB's, dieldrin, and eggshell thickness were correlated with DDE; these correlations may account for the associations of productivity with the first three variables. It is unlikely that PCB's could have been a cause of hatching failure because productivity has increased since 1973, while PCB contamination remained high (Fig. 1). Mercury residues are not related to productivity (Table 1). Our finding (Table 1 and Fig. 1) that productivity of ospreys improved after DDE residues in eggs fell below about 60 ppm, dry weight, is consistent with the findings of Henny *et al.* (*9*) that productivity of ospreys in other areas was low when DDE residues were about 14 ppm, wet weight, that is, about 70 ppm, dry weight.

Circumstantial evidence suggests that local contamination with dieldrin affected productivity or survival (or both) of ospreys in the Connecticut River estuary. In the period 1960 to 1965 this colony declined at an annual rate of 31 percent (*2, 3*), a figure much higher than the mortality rate for adult ospreys estimated from banding data (*17*); in 1967 an adult osprey was found dying of dieldrin poisoning (*4*). In 1969 to 1973 the mean productivity of ospreys in this estuary was 0.31 young per pair, significantly lower than that in the remainder of the area ($P < .01$; Mann-Whitney U test); dieldrin residues at that time were significantly higher in the estuary ospreys (2.2 ppm, $N = 8$, compared to 1.2 ppm, $N = 44$; arithmetic means, $P < .01$, Mann-Whitney U test). Earlier, in 1964 to 1969, dieldrin levels in osprey eggs from the Connecticut River estuary were even higher [arithmetic mean 3.4 ppm, dry weight, estimated from wet weight values (*4*); $N = 24$]. These values are within the range reported in eggs of populations of the golden eagles (*Aquila chrysaetos*) and sparrowhawks (*Accipiter nisus*) in Great Britain that were experiencing reproductive failures associated with dieldrin contamination (*18*). Samples of water and fish from the Connecticut River had unusually high residues of dieldrin during this period (*19*). This contamination of the Connecticut River has been attributed to discharge from four woolen mills situated upstream (*20*), and was presumably abated after the registration of dieldrin for mothproofing wool was canceled in 1972 (*21*). Effects of dieldrin on the ospreys appear therefore to have been local in nature, in contrast to the more widespread effects of DDE.

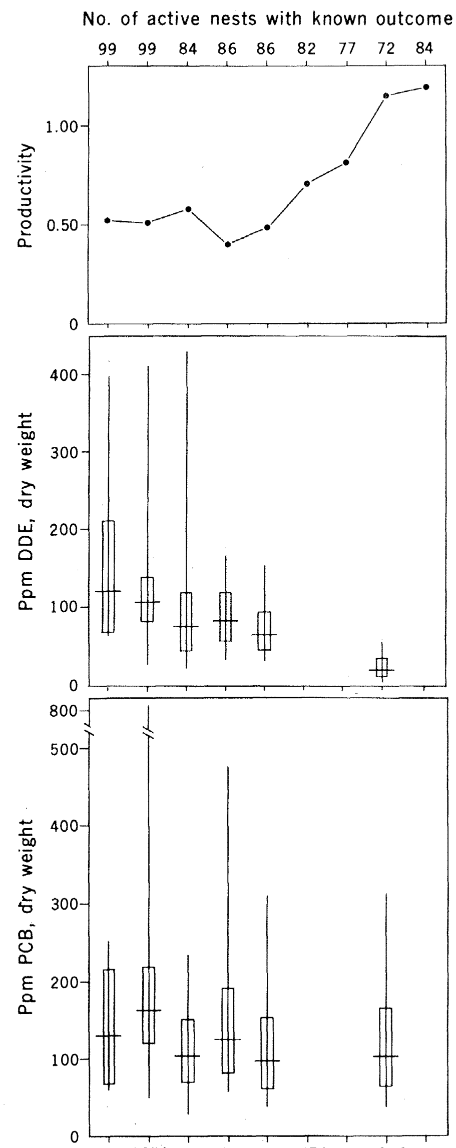

Fig. 1. Active nests of ospreys in Connecticut–Long Island with known outcome, 1969 to 1977; productivity, defined as young fledged per active nest; DDE and PCB residues, parts per million dry weight, with the sample sizes. Horizontal bars are geometric means; rectangles are the 95 percent confidence intervals of the means; vertical lines are the sample ranges.

On the Pacific Coast reproductive recovery of the brown pelican (*Pelecanus occidentalis*) followed the elimination of a point source of DDE and other DDT compounds (*22*). In the C-LI area, the decline in environmental residues of DDE and the associated recovery of the ospreys appear to have been a more direct result of the administrative decisions ending use of DDT in the United States (*12*).

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"Resolution" of Diploid-Tetraploid Tree Frogs

In their report on the albumin immunology of the diploid-tetraploid species complex of *Hyla chrysoscelis* and *Hyla versicolor* (*1*), Maxson *et al.* state that all *H. chrysoscelis* individuals tested against both antiserums could be unequivocally assigned to either the eastern or western population group. However, this statement is then contradicted by a note (*2*). The two diploid heterozygous individuals from the Angelina National Forest in extreme eastern Texas are explained away as "occasional hybrids" between eastern and western *H. chrysoscelis*. Examination of a range map of the complex (*3*) would have revealed that, less than 40 km to the west of this locality, the tetraploid *H. versicolor* completely divides the range of *H. chrysoscelis* westward to central Texas and northward from the Texas and Louisiana coasts to southwestern Missouri. "Occasional" hybridization in southwestern Missouri could scarcely account for the appearance of two of two heterozygous individuals in extreme eastern Texas. If Maxson *et al.* are proposing that two distinct forms of *H. chrysoscelis* that rarely hybridize coexist in eastern Texas (that is, are distinct species), then the probability that two of two randomly selected individuals would both be hybrids is infinitesimally small. Moreover, the data they present are not relevant to the question of specific status. Species distinctness of sympatric forms is determined by fieldwork, not by immunological distances. In addition, moderate frequencies of the eastern allele in western populations, and vice versa, could very well have gone undetected simply because sample sizes are only three to five individuals (six to ten genes) per population (*1*). Therefore the data at worst contradict, and at best provide no support for, the statement (*1*) that eastern and western *H. chrysoscelis* have ever maintained separate gene pools.

Nor do the data support the statement (*1*) that gene exchanges between the two forms of *H. chrysoscelis* have not been evolutionarily significant in the last 4 million years. The genetically intermediate tetraploid *H. versicolor* (*1*, *4*) must have arisen from either a continuously existing intermediate population of *H. chrysoscelis*, or from one or more heterozygous individuals produced as a result of secondary contact of the two forms. Either case represents evolutionarily significant gene exchange between the two forms subsequent to their acquisition of different major albumin alleles.

To demonstrate that the two forms of *H. chrysoscelis* are genetically different enough to have produced an allotetraploid, Maxson *et al.* state (*1*) that the formation of quadrivalents during meiosis, as occurs in *H. versicolor*, is often taken as an indication of allopolyploidy in plants. This is a complete reversal of the generally accepted view (*5*).

The average distance between the albumins of eastern and western *H. chrysoscelis* is approximately 7 immunological distance units (IDU) (*1*). Consistent with a number of assumptions about IDU's and amino acid substitutions in frog albumins, and the rate of evolution of frog albumins (*6*), the genetic difference inferred from this distance is thought to be too large to be a simple geographic allele frequency difference within a single, wide-ranging species. Despite claims to the contrary (*1*), sample procedures, sample sizes, and statistical analyses of results in prior albumin immunological studies (*7*) have not been suitable for detecting albumin immunoalleles in populations. This possibility has been ignored in interpretations of results in these studies (*6*, *7*).

The average distance of about 7 IDU (a calculated divergence time of approximately 4 million years) is used in a fashion unwarranted by the statistical situation. First, tests of eastern albumin with western antiserum and western albumin with eastern antiserum differ from a perfect reciprocity by 100 percent (an average immunological distance of 4.5 in the former test and of 9.3 in the latter). The difference in the reciprocal tests is highly significant ($P < .001$). Combining them to obtain an average of 7 IDU is not statistically valid. Furthermore, since the eastern and western albumins are tested directly against each other and not against that of a third form, it is illogical to attribute the deviation from perfect reciprocity to "a different number of amino acid substitutions in the albumins of the eastern and western lineages since they last shared a common ancestor" [reference 13 in (*1*)]. Therefore the actual distance could be as small as 4.5 ± 1.7 IDU. Second, a figure of $\pm$ 2 IDU, which is characterized as "expected from the normal polymorphic structure of evolving populations" is elsewhere given as the maximum standard deviation observed "on repeated runs of a single sample" [reference 12 in (*1*)]. Finally, interindividual standard deviations range from $\pm$ 0.7 IDU to $\pm$ 1.7 IDU in the sample groups. Given this variation, one can seriously question whether the average immunological distance of 7 between the eastern and western albumins represents a reasonable measure of genetic distance between the two forms of *H. chrysoscelis*. The actual immunological distance could be small enough to be accounted for by only one or two amino acid substitutions.

Maxson *et al.* demonstrate that there are two albumin immunoalleles in this complex (*1*). They also show that one is present in major frequency in eastern *H. chrysoscelis* populations as far west as Mississippi, the other present in major frequency in central Texas (western) *H. chrysoscelis* populations, and that both are present in Texas populations of the

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