

Productivity in Relation to Residue Levels of DDE in the Eggs of White-Tailed Sea Eagles *Haliaeetus albicilla* in Sweden

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The reproductive ability of the White-tailed Sea Eagle on the Swedish coast of the Baltic Sea began to deteriorate during the 1950s and reached its bottom level during the 1970s (Helander 1985). Sea Eagle populations on the Finnish and Estonian coasts of the Baltic demonstrated similar poor reproductive results during the 1970s (Stjernberg *et al.* 1990, Randla 1976), indicating a common cause connected with the Baltic ecosystem. Since the Baltic is heavily polluted, it has been important to assess the possible influence of chemical compounds on the reproductive ability of the Sea Eagle in this region.

Koivusaari *et al.* (1980) reported a significant decrease of DDE in Sea Eagle eggs from the northern Baltic in 1972-1978 and an (insignificant) increase in productivity in this population in 1974-1978 as compared to 1969-1973. PCB and mercury levels in the eggs did not change during this period and it was suggested that the decrease in DDE was the most obvious reason for the increasing productivity. Studying populations on the central and southern Baltic coast, Helander *et al.* (1982) found significantly lower levels of DDE and PCBs in fertile as compared to infertile clutches and in eggs from productive as compared to unproductive pairs; the lowest levels occurred in eggs from successful breeding attempts. Mercury levels were equal in all the groups. The correlation between the levels of DDTs and PCBs in the eggs made it difficult to separate their effects on reproduction within the population. A comparative study based on data from different Sea Eagle and Bald Eagle, *Haliaeetus leucocephalus*, populations indicated a stronger correlation for DDE with reduced productivity than for PCBs. Attempting to study whether interannual variations in residue levels could explain breeding failures of otherwise successful pairs, Helander (1983) compared Sea Eagle eggs from: 1) successful nests, 2) otherwise productive nests that failed due to human disturbance, and 3) otherwise productive nests that failed without any indication of disturbance. There was no significant difference among the groups in PCB or mercury levels, and between the first and second group in DDE levels, but the DDE levels were significantly higher in the latter group. These investigations all indicated that DDE had the strongest influence on Sea Eagle reproduction.

Wiemeyer *et al.* (1984) found that the reproductive ability of Bald Eagles in 14 states in the USA was most closely correlated with DDE in the eggs, and that reproductive failure approached 100% where DDE levels in the eggs exceeded 15 ppm (wet weight). This suggests that there is a difference in sensitivity to DDE between Bald Eagles and Sea Eagles, for which Helander *et al.* (1982) reported an average of 26 ppm DDE in eggs from successful nests.

This paper presents data on productivity in relation to residue levels of DDE in the eggs of White-tailed Sea Eagles on the Swedish Baltic coast to complement similar data for the Bald Eagle presented by Jenkins *et al.* (this volume).

MATERIALS AND METHODS

The breeding success of the Swedish Baltic Sea Eagle population has been surveyed annually since 1964. Nests were inspected about 4 weeks after normal hatching time to determine the outcome of breeding attempts and to collect unhatched eggs and shell fragments for investigations. Eggs were collected only occasionally in 1964-1970 (8 clutches) but systematically in 1971-1992 (123 clutches). Individual eggs were analyzed for residue levels of organochlorines according to Jensen *et al.* (1979), at the Swedish Museum of Natural History and the National Swedish Environment Protection Agency Special Analytical Laboratory. The sum of DDTs consisted almost exclusively of DDE (*p,p'*-DDT was not found in any of the samples and *p,p'*-DDD averaged less than 1% of the analyzed DDT components) and is further denoted as DDE. When more than 1 egg was analyzed from a clutch, the arithmetic mean level was used.

Productivity, defined as the average number of young produced per year (yr) was calculated for each territory from all breeding attempts with known outcome during a 5-yr period consisting of the egg-sampling yrs ± 2 yrs. Breeding attempts that failed after strong disturbance at the nest were excluded, as were those yrs when subadults occurred in the mated pairs, resulting in no egg production; yrs when adult pairs produced no eggs were included in the productivity calculations. From some territories, eggs obtained within a 5-yr period represented the same female. When 5-yr periods around a sampling year overlapped, a longer period including 2 or more sampling yrs ± 2 yrs was designated and the arithmetic mean level of DDE from the clutches included was related to the average productivity for the whole period. This was done in order to avoid an over-representation of some females; it restricted the material to a total of 78 sets of data.

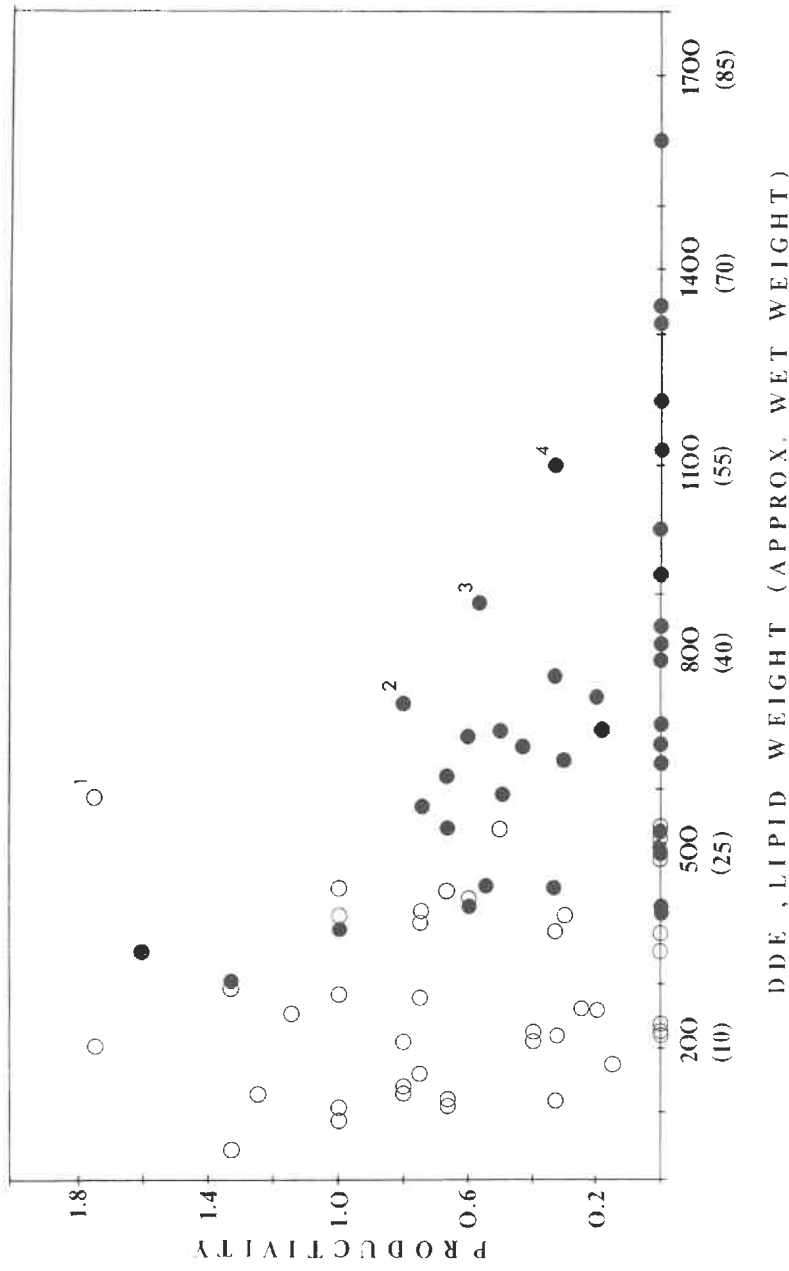
RESULTS AND DISCUSSION

There is an obvious decline in productivity with increasing levels of DDE in the eggs (Figure 1). To simplify comparison with other investigations, the scale in the figure indicates both lipid weight (lw) and the approximate corresponding wet weight (ww) values, assuming an average fat content in the eggs of about 5% (from calculations of original fat contents by Helander *et al.* (1982) based on total egg volume, here adjusted upwards to compensate for the airsac).

With one exception, productivity was lower than 1.0 when DDE reached 500 ppm lw (25 ppm ww) and virtually no reproduction occurred (again with one exception) when DDE concentrations exceeded 900 ppm lw (45 ppm ww). At DDE concentrations of 300-400 ppm lw (15-20 ppm ww), several pairs demonstrated a productivity between 1.0 and 1.75, which is in the range considered normal for the species in this region before the appearance of DDE (Helander, this volume).

The four numbered circles (Figure 1), representing higher productivity at high levels of DDE, deserve some comments. No. 1 represents one single egg from a successful breeding attempt; the productivity figure is based on 4 broods (a 5th brood was destroyed by human disturbance soon after hatching and was excluded from the calculations). This case indicates either that some females are able to reproduce normally at DDE levels close to 600 ppm lw (about 30 ppm ww), or the collected egg was not representative of the female. Helander *et al.* (1982) found that the intra-clutch variation in DDE levels in 15 Sea Eagle clutches averaged only about 10% from the clutch mean; thus, single eggs can in most cases be considered representative of the clutch. However, the range in deviation from the mean was up to 29%; some clutches therefore would contain one egg with almost twice the DDE level of the other. From the DDE-productivity relationship, it is likely that the more contaminated egg in such clutches would not hatch. It cannot be excluded that No. 1 is such an "outlier".

Figure 1. Residue levels of DDE (ppm, mg/kg) in White-tailed Sea Eagle eggs and the corresponding productivity (average number of young produced per yr during a 5 yr period; yr of egg sampling $\pm$ 2 yrs or longer; for details, see Material and Methods). Residue levels are given on a lipid weight basis with the corresponding approximate wet weight levels in brackets (based on an average original lipid content of 5% in the eggs). Filled circles, eggs collected during the 1960s and 1970s; unfilled circles, eggs collected during the 1980s and 1990s.



No. 2 represents the average DDE level in eggs from 3 successful breeding attempts over a 7 yr period and the productivity over a 10 yr period, all representing the same female. The range in DDE levels between the clutches was fairly small (650-860 ppm lw). Unless all 3 eggs represent "outliers" as discussed above it appears safe to conclude that some Sea Eagle females can keep up a productivity at DDE levels of about 700 ppm lw (about 35 ppm ww), although this is obviously rare. No. 3 represents the average DDE level in 2 eggs from unsuccessful breeding attempts 2 yrs apart and the productivity over a 7 yr period for the same female; the DDE levels were 900 and 870 ppm lw, respectively. No. 4, on the other hand, is based on weaker data: a single egg from the last, unsuccessful breeding attempt of a female and productivity for only a 3 yr period.

The approximate ww values corresponding to the lw values as given in Figure 1 should be treated with some caution, since they are based on an average fat content in Sea Eagle eggs. Fat contents in the eggs vary, however, and for eggs with fat contents deviating considerably from the mean the DDE levels on a lipid weight basis are not actually corresponding to the ww values as suggested in the figure. As an example, the egg in set No. 4 contained only about 4.1% lipids and thus had a true DDE level of "only" about 45 ppm on a ww basis, as compared to a derived level of 55 ppm based on an assumed fat content of 5%.

The distribution in Figure 1 of filled circles, representing eggs from the 1960s and 70s, and of unfilled circles, representing the 1980s and 90s, clearly demonstrates an improvement during the latter period with regard to the contamination with DDE. The levels have not exceeded 600 ppm in the eggs from the 1980s and 90s, whereas 2/3 of the eggs exceeded that level during the 1960s and 70s, reaching as high as 1800-1900 ppm (lw) in some clutches (disguised in averages in the figure). A corresponding improvement in productivity has taken place: only 8% of the data sets from the 1960s and 70s represented a productivity of 1.0, as compared to 27% in more recent years.

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