Seasonal Changes in Organochlorine Compounds and Mercury in Common Terns of Hamilton Harbour, Ontario

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GILBERTSON and REYNOLDS (1) reported the contamination of eggs of Common Terns (Sterna hirundo) with organochlorine substances. These eggs were collected in 1970 from colonies on two artificial islands in Hamilton Harbour, Ontario. In 1971, the characteristics of this contamination were investigated by analysis of eggs collected throughout the breeding season. Several of the first clutches disappeared, broke, or failed to hatch, and the incidence of re-laying was high. Since the islands were visited only twice weekly, it was not possible to obtain information on the exact date on which each egg was laid. However, the date of the visit on which each egg was first seen is known, and was used to select eggs for analysis. This calendar date has been converted to a season date, where day 1 represents 18 April, 1971; the day on which Common Terns were first seen around the islands during that year. The arrival of the birds at these colonies appears to have been synchronous and probably did not extend over more than a ten day period.

Thirty-two eggs or newly hatched chicks were analysed, corresponding to eggs laid between season dates 30 and 90. Similarly, five adult Common Terns were collected by netting and correspond to season dates 18, 32, 32, 48 and 68. The method of analysis ofr organochlorine substances was outlined by REYNOLDS (2). Total mercury was determined by the method outlined by VERMEER (3). Results of the organochlorine analyses of the eggs and chicks are expressed on a dry-weight basis since they had a variable moisture content. Though the moisture content in the breast muscle of the adult terns did not vary by mroe than 1.2%, the results are expressed on a dry-matter basis for consistency. The results of the analyses for mercury are expressed on a wet-weight basis for both the eggs and chicks and for the breast muscle of the adults. Though both eggs and hatched chicks have been used in this analysis the data on residues are comparable. COOKE (4) found that incubating eggs of DDT-fed Japanese Quail (Coturnix coturnix japonica) did not affect total pesticide residues in the eggs, but that the embryo metabolized DDT to DDE after 10 days. DDT and DDD in these tern samples were frequently undetectable or less than 1% of the DDE. The possibility that there was metabolism of dieldrin and PCB during incubation cannot be excluded, but it is unlikely to be significant. No correction has been made for the small decrease in dry matter content during incubation.

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Results and Discussion

1. Organochlorine contamination

(a) Eggs and hatched chicks

Figure 1 shows the DDE contamination of the eggs versus season date. Performing an analysis of variance, there was a close relationship ($F_{1,30} = 52.0$, $p < 0.01$) between the increase in contamination and the season date. The form of the regression line indicates that the birds returned from winter migration with levels of DDE which were small in relation to the concentrations which accumulated during the season.

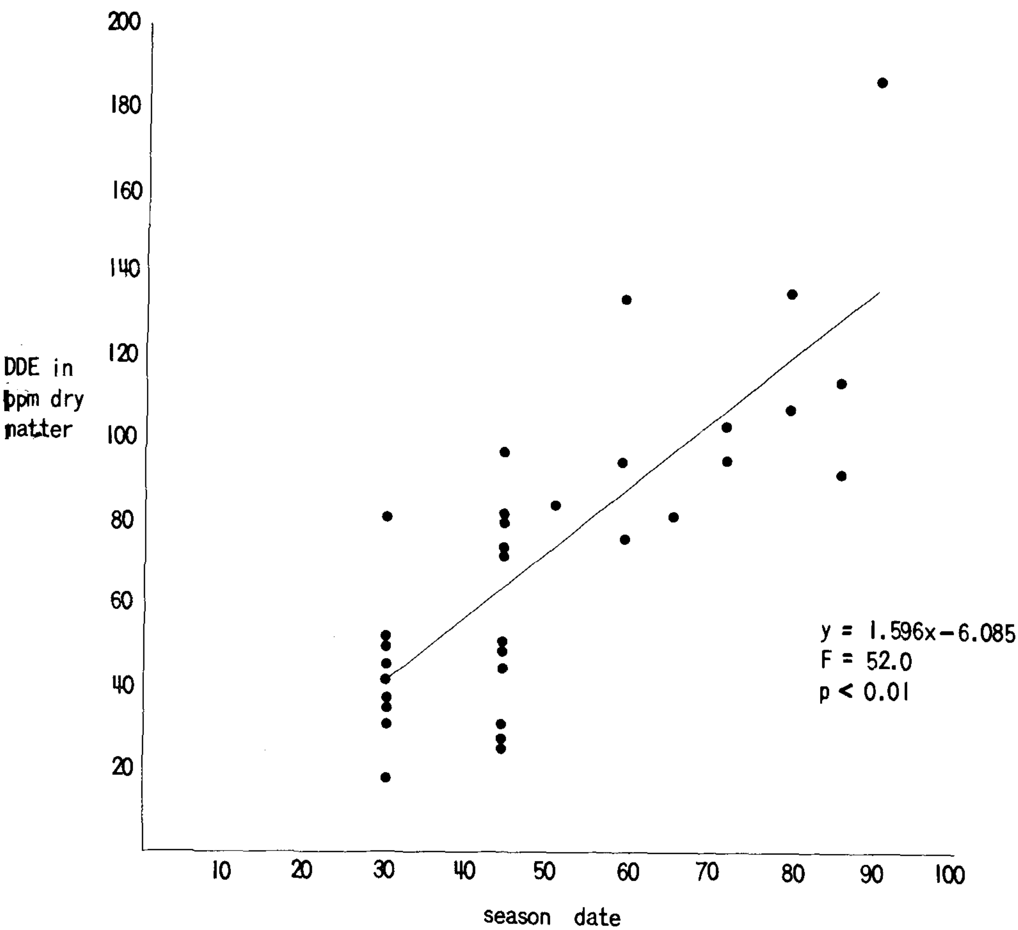

Figure 1 DDE content of Common Tern eggs versus season date

Table 1 shows the equations of the least squares linear regression line, the product moment and Spearman rank correlation coefficients and proability value for the latter for the increase of DDE, hexachlorobenzene, dieldrin, and PCB with season date. HCB and dieldrin increased in a manner similar to DDE.

Though the Spearman rank correlation coefficient between PCB and season date was significant ($r = 0.3962$, $p < 0.05$) the product moment correlation coefficient was not ($r = 0.3411$, $p > 0.05$). There was however a very significant product moment correlation between the concentration of DDE and PCB ($r = 0.7282$, $p < 0.01$). The form of the distribution of the concentrations indicated a non-linear relationship. The correlation coefficient of the logarithmic transformation of the concentrations of DDE and PCB was higher than the coefficients on the untransformed data ($r = 0.8120$, log DDE v. log PCB; $r = 0.7661$, log DDE v. PCB; $r = 0.7112$, DDE v. log PCB). Figure 2 shows the regression of log PCB on log DDE and 95% confidence limits and indicates that PCB was not found in the same relative proportion as DDE with time. A product moment and Spearman rank correlation coefficient has been calculated for the PCB/DDE ratio versus time. There was a significant logarithmic product moment correlation between the decrease in the logarithm of the ratio and the logarithm of the season date ($r = -0.8076$; $p < 0.01$, $\log y = 3.0048 - 0.7231 \log x$) and a significant Spearman rank correlation coefficient ($r = -0.8565$, $p < 0.01$). Pooled samples of alewives (*Alosa pseudoharengus*), smelt (*Osmerus mordax*) and stickelbacks (*Gasterosteus aculeatus*), analysed in the same way from feeding areas of the terns, contained residues of PCB and total DDT with a ratio of between 2.3 and 2.9. The rate of increase of PCB with time, indicated by the egg data, was 2.73 ppm/day and the rate for DDE increase was 1.60 ppm/day. The ratio between the two rates is 1.7. Thus the results indicate firstly, that the terns arrived from migration with a significant content of PCB but negligible DDE and that subsequently they became contaminated at the breeding site with both DDE and PCB, the ratio of PCB to DDE decreasing with time to approximate the ratio in the fish in the vicinity of the colony.

Secondly, the discrepancy between the ratio of PCB to DDE in the fish and the rates found in the eggs with time may indicate that the birds may have metabolised PCB's.

(b) Adult birds

Table 2 shows the equations of the least squares linear regression line, the product moment and Spearman rank correlation coefficients and probability value for the latter for the contaminants dieldrin, hexachlorobenzene, PCB and DDE in the breast muscle of the adult Common Terns versus season date. All these substances increased significantly with time, supporting the conclusion drawn from the results of the analyses of the eggs that contamination was of local origin.

TABLE 1

Statistics of organochlorine and heavy metal contamination of 32 eggs of Common Terns versus season date

	Equation of linear regression	Product moment correlation coefficient	Spearman rank correlation coefficient	Probability value
Organochlorines (in ppm dry water)				
DDE	$y = 1.596\,x - 6.805$	0.7954	0.7749	< 0.01
Hexachloro-bezene	$y = 0.088\,x + 0.077$	0.7075	0.7927	< 0.01
Dieldrin	$y = 0.040\,x + 0.396$	0.6900	0.7323	< 0.01
PCB	$y = 2.730\,x + 291.6$	0.3411	0.3962	< 0.05
Heavy metal (in ppm wet weight)				
Mercury	$y = 1.075 + 0.00x$	0.0000	0.1784	> 0.1

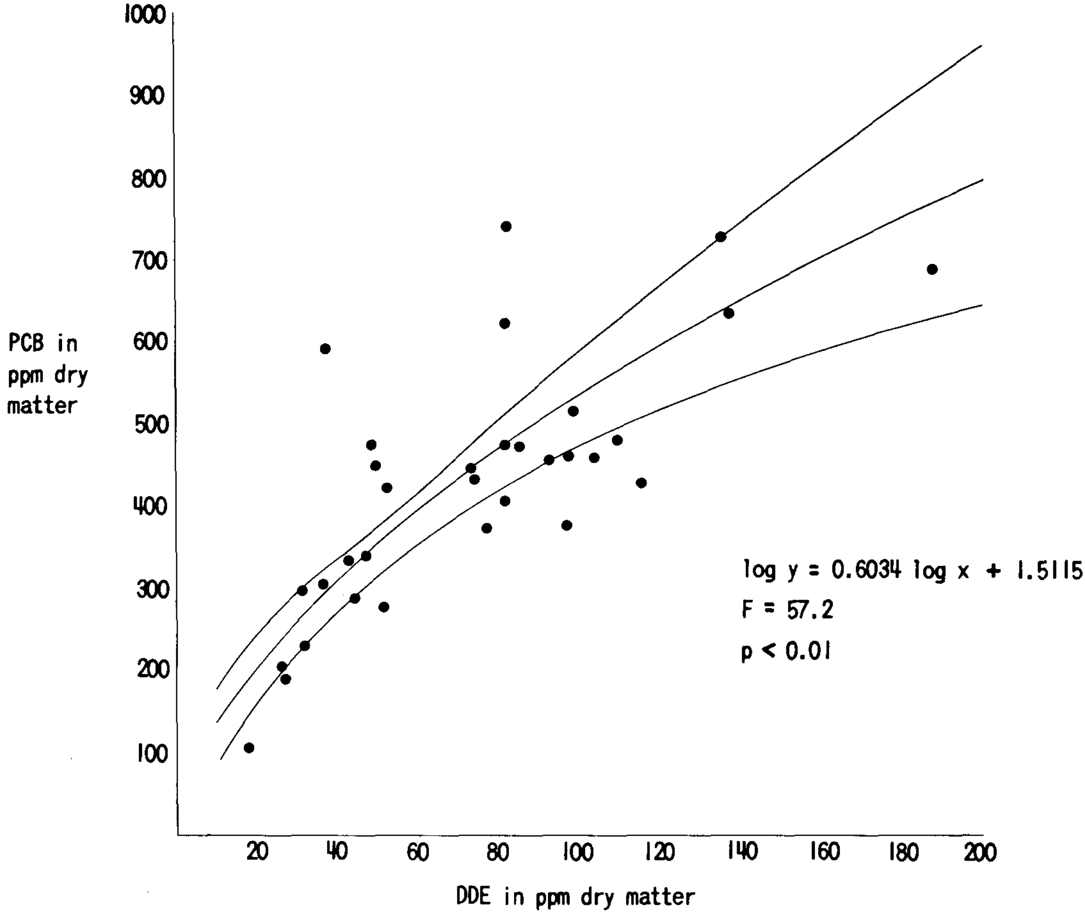

Figure 2 DDE and PCB in Common Tern eggs

2. Mercury

Table 2 shows that the correlation between mercury in the eggs and season date was not significant at the five percent level. However, Table 2 indicates that the converse was found for the concentration of mercury in the breast muscle of the adults. Though the Spearman rank correlation coefficient was not significant this was due to two birds of the small sample of five being caught on season date 32 and one of these having a lower value than a bird caught on season date 18. Performing a linear regression on the data there was a significatn relationship ($F_{1,3} = 26.76$, $p < 0.05$) between the level of mercury in the breast muscle and season date. These results are consistent with those found with experimental feeding of methyl mercury dicyandiamide to poultry (Gallus domesticus) (5) and to pheasants (Phasianus colchicus) (6). Mercury in the blood is bound to the protein (7). ROMANOFF and ROMANOFF (8) stated that the proteins in the yolk and albumen of the

TABLE 2

Statistics of organochlorine and heavy metal contamination of the breast muscle of 5 adult Common Terns versus season date

	Equation of linear regression	Product moment correlation coefficient	Spearman rank correlation coefficient	Probability value
Organochlorines (in ppm dry matter)				
Dieldrin	$y = 0.0142\,x + 0.032$	0.9660	0.9750	< 0.01
Hexachloro-benzene	$y = 0.0370\,x - 0.0327$	0.9547	0.9750	< 0.01
PCB	$y = 2.723\,x + 15.83$	0.9420	0.9750	< 0.01
DDE	$y = 0.5728\,x - 3.437$	0.9418	0.9750	< 0.01
Heavy metal (in ppm wet weight)				
Mercury	$y = 0.0235\,x - 0.135$	0.9484	0.8250	> 0.05

egg are derived from the proteins of the blood serum in hens. Thus the level of mercury in the tern eggs would be expected to remain constant throughout the season since it is derived from the mercury bound to the serum protein which is assumed to be dependent upon the level in the food rather than the amount stored in the tissues. The distribution of the concentrations in the eggs indicated that the mercury levels in the serum protein reach an equilibrium concentration before the start of egg laying and thus reflect the level of mercury contamination in the fish in the local environment. Analyses of total mercury in the fish samples showed that the residue content varied between 0.07 and 0.21 ppm (wet weight).

Conclusion

This study has shown that the concentration of organochlorine substances in Common Terns and their eggs can vary considerably during a single breeding season. Similarly the levels of mercury in the breast muscle of adult Common Terns varied with time but levels in the eggs did not vary through the breeding season. It is concluded that the organochlorine substances reported in this paper and the mercury were mainly ingested in the vicinity of the colony. Studies of residues and breeding success of fish-eating birds, which may be affected by pollutants, should take account of such seasonal variation in organochlorine and mercury substances which occurs amongst colonies of birds nesting in contaminated environments.

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