Reproduction and Pesticide Residues in Orchard Passerine Populations in Denmark

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INTRODUCTION

In the Danish landscape the orchards are probably the part which each year receive the greatest amount of pesticides. Normally fungicides, acaricides, and insecticides are applied several times during the summer half. The pesticide committee of the Danish Ornithological Society therefore made it their concern to start an investigation on the effect of this intense spraying on the avifauna in the orchards and their immediate vicinities. It was decided to concentrate on hole-nesting, insectivorous birds the breeding success of which could be followed in nestboxes.

Unhatched eggs and dead nestlings should be collected and analysed for residues of the most persistent among the insecticides used, viz. DDT and lindane.

When this work was started in 1964, no previous analyses had been made of passerine birds from biotopes in Denmark where the insecticidal pressure was known, and neither had methodical observations on their reproduction in sprayed areas.

MATERIALS AND METHODS

Study Areas and the Arrangement of Nestboxes

Three orchards in North Zealand were selected for the investigation: Bøgebjerggård (B), Granhøjgård (G), and Lillevang (L). They are all dominated by appletrees and surrounded and divided up by hedgerows, mainly of poplars.

In B 81 nestboxes were placed at a fruit tree area of ca. 16 hectares in hedgerows and in unutilized areas inside the orchard: Two small wooded hills and thickets around two ponds. The surroundings consist of permanent grassland, fields, ponds, other orchards, and gardens.

In G 100 nestboxes were set up at a fruit tree area of ca. 16 hectares. The surroundings are rather varied: Ponds, meadows, bog with scrub of alders, grassland, a small wood, fields, young plantations, and other orchards.

In L 68 nestboxes were placed around an orchard area of ca. 8 hectares, partly in the fringe and the nearest part of an extensive and varied wood that adjoins the orchard to the north. To the other sides are fields, gardens, and other orchards.

The nestboxes were of the "Schwegler", 1B-type, made of sawdust concrete.

Most of the boxes were scattered along the hedgerows, not among the fruit trees themselves. Wherever possible their position was 1.5-2 m above the ground, not directly exposed to the sun. They were all set up in February 1964 and kept under observation during the breeding seasons 1964, 1965, and 1966.

Spraying with Pesticides

Spraying was carried out according to the normal schedule of the orchards regardless of the bird observations. The spraying schedules are summarized in Table 1. For each year the total amount of insecticides and acaricides applied per ha is given during the nestling period and during the rest of the season. As to the fungicides, only the number of sprayings are given; a great number of compounds was used, especially sulphur and thiram. The estimation of dosage/ha is based on the concentration of the preparation concerned, the dilution for spraying, and application of 2500 l/ha of the prepared spray. This estimation does only roughly represent a mean value, as the amount of spray used varies considerably according to the size of the trees.

In B the choice of pesticides, with decreasing use of chlorinated hydrocarbons (DDT and lindane), and the frequency of spraying were rather typical to Danish orchards.

In G the amount of chlorinated hydrocarbons was rather high, but the schedules in most respects typical.

In L only DDT and lindane were used as insecticides, and fungicides were applied more frequently than in most orchards.

An inquiry was undertaken among the owners of larger areas surrounding the orchards in order to establish the extent of pesticide application. With a few exceptions the farm-areas and the woods were not treated. Other orchard areas in the neighbourhood especially of B and L were sprayed to the same extent as the study areas, and in all three cases neighbouring gardens may also have contributed to the influence of pesticides.

Reference Areas

As comparable orchards without pesticide spraying proved impossible to find, we have used data for comparison from the same years from three areas in North Zealand where nestboxes are permanently present: Gammelmosen (Ga), Marienborg (M), and Rungstedlund (R).

Ga is a ca. 20 hectares bog, dominated by birches and alders. In neighbouring gardens and a hospital park limited use of pesticides took place.

M is a 10 hectares park, mainly a low-lying area with birches and alders bordering a stream. It is surrounded by woods and bogs.

R is a bird sanctuary in a ca. 8 hectares park with a variety of deciduous trees. As in M, no pesticides were used in the park nor in the neighbouring properties in the years of concern.

Finally, a few data have been taken for comparison from nestboxes set up in an area with conifers in Gribskov (GW) as decribed by Bejer-Petersen *et al.* (1972).

Weekly Inspections

If possible, the nestboxes were inspected every week in the breeding season. Species and numbers of eggs and nestlings and the estimated age of the nestlings were registered, and it was observed if the adult birds were inside the box or in the vicinity. Incubating birds were not removed, but the counting of their eggs was postponed to the next inspection. Dead nestlings were recorded and, if not too decomposed, collected in tins for analysis. Eggs left in the nest after the normal incubation time were also collected. Most of the nestlings were ringed.

In the winters 1965-66 and 1966-67 some nigthly inspections were carried out.

One brood of nearly fullgrown Great Tit nestlings from each of the orchards were killed 15.VI 1966 for analysis in order to check the content of lindane and DDT in living birds. In addition healthy individuals were taken for analysis from five other Great Tit broods in L. One Great Tit brood killed accidentally (L 1966) was also analysed.

In cases where the number of nestlings plus unhatched eggs in a nestbox was found to be lower than the number of eggs laid, the difference is considered to represent nestlings dying shortly after hatching and removed by the parent birds (compare Seel 1968 b).

Chemical Analysis

During 1965 and 1966 eggs and dead nestlings were collected for estimation of residues of lindane (γ – 1,2,3,4,5,6 – hexachlorocyclohexane), DDT (1,1,1 – trichloro – 2,2 – bis (p – chlorophenyl) – ethane), DDD (1,1 – dichloro – 2,2 – bis (p – chlorophenyl) – ethane), and DDE (1,1 – dichloro – 2,2γ bis (p – chlorophenyl) – ethylene).

The analyses of the eggs have been made on the mixed yolk and white. Separation of the yolk from the white was impossible in several cases; furthermore, embryos were found in some eggs. The nestlings were analysed after skin and extremities had been removed. Single organs could not be dissected due to putrefaction or to drying out.

The figures in Table 4 and 8 refer to the analysis of pooled eggs or nestlings from the boxes in question whenever reference is made to more than one individual.

The procedure has been that of Stemp *et al.* (1964). For eluating purpose 6 % ether dissolved in petrol ether has been used to avoid evaporation till dryness and thereby diminishing the loss

Tabel 1. Summary of spraying with pesticides in the orchards. The total amounts for the nestling period and for the rest of the season are expressed as kg active ingredient per ha. Figures in brackets give number of spraying within the period in question.

Tabel 1. Oversigt over sprøjtningen med pesticider i frugtplantagerne. De totale doser for den periode, hvor der var unger i redekasserne, og for den øvrige del af sæsonen er angivet i kg aktivt stof pr. ha. Tallene i parentes angiver antallet af sprøjtninger i den pågældende periode.

Orchard *Plantage*	Year *År*	Nestlings present *Unger i reder*	Insecticides *Insektmidler* DDT	lindane	parathion	carbaryl	azinphos-methyl	demeton-S-methyl	oxydemeton methyl	Acaricides *Midemidler* binapacryl	chlorbenside	Fungicides *Svampemidler*
B	1964	16.V – 26.VII	2.9 (2)	0.3 (1)	1.2 (3)	6.2 (2)		0.6 (1)			0.5 (1)	(7)
		Outside this period	1.0 (2)	0.6 (2)							0.5 (1)	(3)
	1965	20.V – 8.VII	2.3 (2)	0.8 (2)				0.6[1]) (1)		1.3 (1)	0.5 (1)	(4)
		Outside this period			1.4 (3)							(8)
	1966	25.V – 29.VI	0.6 (1)	0.3 (1)		3.1[1]) (1)	1.3 (1)			1.3 (1)		(3)
		Outside this period[2])			0.5 (1)		1.3 (1)					(4)
G	1964	16.V – 21.VIII	5.4 (4)	1.0 (3)	0.8[1]) (2)					1.0 (1)	0.5 (1)	(7)
		Outside this period			0.4 (1)							(8)
	1965	14.V – 20.VII	1.6[1]) (1)	1.0[1]) (2)	0.4[1]) (1)	2.5[1]) (1)				3.6[1]) (3)		(7)
		Outside this period	1.9[1]) (1)		1.2[1] (3)							(11)
	1966	20.V – 19.VIII	2.3 (2)	0.3 (1)					0.6 (1)	1.3[1]) (1)	0.2 (1)	(8)
		Outside this period			1.0 (2)							(6)
L	1964	15.V – 22.VII	2.4 (3)	1.0 (3)						1.0 (1)	1.0 (2)	(10)
		Outside this period	1.0 (2)	0.6 (2)							0.5 (1)	(15)
	1965	16.V – 4.VII	1.0 (2)	0.8 (2)						2.6 (2)	0.5 (1)	(7)
		Outside this period	1.0 (2)	0.6 (2)							0.5 (1)	(15)
	1966	21.V – 1.VIII	1.4 (3)	1.4 (4)						2.6 (2)	1.0 (2)	(11)
		Outside this period[2])	0.6 (1)	0.3 (1)								(4)

[1]) Applied to part of the orchard. *Del af plantagen sprøjtet.*

[2]) In B and L 1966 spraying was not recorded after the nestling period. *I B og L 1966 blev sprøjtningen ikke registreret efter at ungerne havde forladt redekasserne.*

of insecticides, particularly lindane (MILLS *et al.* 1963).

By collecting the first 150 ml eluate, 70-80 % lindane and 80-95 % DDE, DDD, and DDT have been recovered.

Detection has been made by gaschromatography using an electron capture detector. 5 % QF_1 on chromosorb W 60-80 mesh as well as XJ 0406 (JENSEN, unpublished) have both served as column material.

As the position of lindane on the chromotogram is found only a few cm from that of the solvent together with some minor unidentified peaks, the lindane concentrations indicated are considered as maximum values. It has not been possible to make any further identification of the compounds having a retention-time identical to that of lindane.

In cases where concentrations of DDT and DDE have exceeded 2-3 ppm these compounds have been further identified qualitatively and semiquantitatively by means of thin-layer chromatography. The plates have been covered with aluminium oxide, and n-heptane has been used for eluating purpose. The spots have been developed by spraying with a 0.5 % alcoholic solution of o-tolidine, and subsequent exposure to ultraviolet light (KAWASHIRO and HOSOGAI 1964).

The values of the concentrations given in the tables are those actually measured, as no correction for analytical loss of insecticides has been made.

As DDT also *post mortem* can be converted to DDD (STICKEL *et al.* 1966), and the material was stored for months before the analyses were done, the figures in the tables are the sum of DDD and DDT, calculated as DDT. The concentrations are given in ppm = µg insecticide per g wet body weight, assuming that no drying up of the samples prior to analyses had occurred. No corrections were made in those cases where considerable drying evidently had occurred.

RESULTS

General

The principal species studied are the Great Tit *(Parus major)*, the Blue Tit *(Parus caeruleus)*, the Pied Flycatcher *(Muscicapa hypoleuca)* and the Tree Sparrow *(Passer montanus)*. A few data are available also on the Marsh Tit *(Parus palustris)* and the Redstart *(Phoenicurus phoenicurus)*. The Coal Tit *(Parus ater)* data have not been analysed as only one pair bred each year.

The three tit species and the Tree Sparrow are largely sedentary in Denmark, and the majority of the birds presumably were present in the vicinity of the orchards during most of the year as can be inferred from their presence in the nestboxes during winter. The Pied Flycatcher and the Redstart are migratory species which arrive to the orchards in May and leave in July/August to spend the winter in Africa.

All the species are insectivorous during the breeding season, feeding to a large extent on caterpillars (LACK 1966). The Tree Sparrow also takes many beetles (HAMMER 1948).

The numbers of pairs of different species breeding in the nestboxes in the orchards and the reference areas are given in Table 2. As breeding pairs are classified those which built nest and started egg-laying. Pairs which gave up their first clutches and relaid therefore are included twice. In Ga and M, however, many cases of renesting occured because of heavy human interference. These relaid clutches are not included. A rather large proportion of the clutches from the reference areas and a few from the orchards are to be excluded from comparisons, because data on breeding success were incomplete.

Residues in adult birds and adult mortality

Table 3 presents results of analysis of adult Great Tits and Pied Flycatchers. DDE is usually present in the greatest concentrations of the compounds analysed for. Total-DDT (ppm DDE + ppm (DDD + DDT)) varies between 0.56 and 17 ppm. Lindane is present in very low concentrations only.

The concentrations are not higher in the birds found dead than in those killed for analysis and far too low to suggest mortality due to poisoning. Thus WURSTER *et*

Table 2. Numbers of pairs of different species breeding in nestboxes set up in the orchards and reference areas.

Tabel 2. Antal ynglende par af forskellige arter i redekasser ophængt i frugtplantagerne og kontrolområderne.

Species	Art	B 1964	B 65	B 66	G 1964	G 65	G 66	L 1964	L 65	L 66	Total in orchards *Total i frugtplantager*	Ga 1964	Ga 65	Ga 66	M 1964	M 65	M 66	R 1964	R 65	R 66	Total in reference areas *Total i kontrolområder*
Great Tit (1st clutches)	*Musvit (1. kuld)*	10	27	19	15	37	26	11	19	14	178	27	32	23	24	28	17	14	21	17	203
Great Tit (2nd clutches)	*Musvit (2. kuld)*	5	0	0	7	0	0	3	0	1	16	0	0	0	1	0	0	0	0	0	1
Blue Tit	*Blåmejse*	3	7	4	4	7	6	1	6	2	40	2	2	4	3	2	8	6	8	4	39
Coal Tit (1st clutches)	*Sortmejse (1. kuld)*	0	0	0	0	0	0	1	1	1	3	0	0	0	0	0	0	0	0	0	0
Coal Tit (2nd clutches)	*Sortmejse (2. kuld)*	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Marsh Tit	*Gråmejse*	0	2	0	2	0	0	0	0	0	4	0	0	0	0	0	0	1	1	3	5
Redstart	*Rødstjert*	1	1	0	1	0	1	0	0	0	4	3	0	2	1	1	5	2	0	2	16
Pied Flycatcher	*Broget Fluesnapper*	0	2	1	0	2	2	5	8	7	27	3	2	4	11	9	10	4	2	0	45
Tree Sparrow (1st clutches)	*Skovspurv (1. kuld)*	0	2	0	5	19	15	0	0	1	42	0	0	0	0	0	0	0	0	0	0
Tree Sparrow (2nd clutches)	*Skovspurv (2. kuld)*	0	0	0	5	13	13	0	1	1	33	0	0	0	0	0	0	0	0	0	0
Tree Sparrow (3rd clutches)	*Skovspurv (3. kuld)*	0	0	0	0	0	9	0	0	0	9	0	0	0	0	0	0	0	0	0	0
Unknown species	*Ukendt art*	0	1	0	0	1	0	0	2	0	4	0	0	0	0	0	0	1	4	0	5
Total		19	42	24	39	79	71	22	37	27	360	35	36	33	40	40	40	28	36	26	314

Table 3. Residues of lindane, DDE and DDT + DDD in adult birds.
Tabel. 3. Indhold af lindan, DDE og DDT + DDD i voksne fugle.

Species *Art*	Sex *Køn*	Orchard *Frugt-plantage*	Year *År*	Box no. *Redekasse nr.*	Date of collection *Dato for indsamling*	ppm lindane	ppm DDE	ppm DDD+ DDT
Great Tit	♀*	B	1965	59	25.V	0.02	4.3	1.7
Musvit	?**	L	1966		15.VI	trace	2.0	0.06
	♂***	G	1967	?	20.IV	ND	5.1	0.46
	♂***	G	1967	?	20.IV	ND	16	0.98
Pied Flycatcher	♀****	G	1966	39	31.V	0.08	0.40	0.59
Broget Fluesnapper	♀****	L	1966	27	14.V	trace	0.50	0.06

ND: Not detected. *Ikke påvist.*
trace: *Spor.*
* Found dead on her eggs. *Fundet død på sine æg.*
** Found road-killed about 1 km from orchard L. *Fundet dræbt på vej ca. 1 km fra frugtplantage L.*
*** Ringed as nestlings in G in 1964 and killed for analysis. *Ringmærket som unge i G i 1964 og aflivet til analyse.*
**** Found dead in nestbox before egg-laying. *Fundet død i redekasse før æglægning.*

al. (1965) find that poisoning may be suggested when whole bird residues of total-DDT are more than 30 ppm. A further suggestion that poisoning was not an important factor of mortality comes from an estimation of the annual adult mortality of the orchard Great Tits from spring 1966 to spring 1967. Maximum annual mortality in two of the orchards were 68 and 56 % which is sligthly less than found in the reference areas and only sligthly more than found in other studies (Kluijver 1951, Lack 1966 and Haukioja 1969). Weights of adult orchard Great Tits in spring did not differ from those of the reference area birds.

Residues in eggs

The pattern of occurrence of pesticides in eggs (Table 4) is similar to that found in adult birds. Total-DDT varies between 0.32 and 102 ppm with DDE as the dominating compound. The median value of total-DDT of the entire material is approximately 8 ppm. Lindane is found in concentrations far lower.

Variability of eggs residues in one species is high; thus total-DDT in Great Tit eggs from orchard G in one breeding season (1965) varies between 1.7 and 102 ppm. This great variability tends to mask species differences. Thus there is no clear evidence that egg residues in the migratory species (Pied Flycatcher, Redstart) are less than in the resident ones. Differing feeding behaviour probably is the reason why Tree Sparrow eggs contain significantly less ($P < 0.002$, Mann-Withney U-test, Siegel 1956) total-DDT than Great Tit eggs from the same orchard in the same breeding season (G 1965). In 1966 residue levels in the two species in the same orchard are similar.

The egg residues in general are higher

Table 4. Residues of lindane, DDE and DDT + DDD in eggs.

Tabel 4. Indhold af lindan, DDE og DDT + DDD i æg.

Species *Art*	Orchard and Year *Frugtplantage og år*	Number of eggs analysed *Antal æg analyseret*	Box no. *Redekasse nr.*	Date of collection *Dato for indsamling*	ppm lindane	ppm DDE	ppm DDD+DDT
Great Tit *Musvit*	B 1965	8	2	17.VII	ND	3.7	0.03
		6	3	8.VIII	trace	11	1.4
		1	11	8.VIII	ND	9.6	2.1
		4	13	17.VII	trace	11	0.60
		4	23	4.VI	ND	9.7	0.74
		3	28	4.VI	ND	8.2	0.51
		2	33	26.VII	ND	2.4	0.43
		4	47	4.VI	ND	9.1	0.39
		3	49	22.VI	ND	11	0.93
		9	59	25.V	trace	7.6	0.61
		1	65	4.VI	trace	2.5	0.14
		1	68	4.VI	ND	3.9	0.46
		1	77	4.VI	trace	13	0.86
		6	80	26.VII	ND	4.6	0.10
	G 1965	1	15	13.VI	ND	5.7	0.33
		2	23	3.VI	trace	17	2.7
		1	34	3.VI	ND	4.3	1.1
		2	37	3.VI	trace	18	1.4
		1	39	13.VI	ND	4.5	0.70
		1	47	13.VI	trace	8.4	0.52
		1	62	3.VI	ND	1.4	0.25
		1	75	13.VI	ND	4.6	0.51
		1*)	92	16.V	ND	24	6.6
		1	96	13.VI	trace	94	8.0
		3	98	3.VI	trace	27	3.8
	L 1965	2	7	4.VII	ND	8.3	1.1
		1	9	19.VI	ND	1.5	2.3
		1	41	19.VI	ND	0.26	0.06
		1	52	27.VI	ND	1.2	0.30
		1	64	4.VII	ND	7.3	0.30
		1	68	4.VII	ND	1.6	0.11
	G 1966	1	10	18.VI	0.42	18	1.2
		1	25	11.VI	0.04	1.1	0.84
		2	31	11.VI	0.02	3.8	1.1
		1	40	11.VI	0.07	7.4	1.3
		1	82	25.VII	0.03	1.6	0.66
		3	86	25. VI	0.20	10	1.3
		1	100	25. VI	0.02	2.7	0.44
	L 1966	10	5	15.VI	0.03	8.9	3.6
		2	25	22.VI	0.04	7.9	0.90
		1	54	22.VI	0.17	12	0.47
		1	55	22.VI	0.05	3.2	0.16
		1	60	22.VI	0.08	8.5	0.43

Table 4. Continued

Tabel 4. Fortsat

Species *Art*	Orchard and Year *Frugtplantage og år*	Number of eggs analysed *Antal æg analyseret*	Box no. *Redekasse nr.*	Date of collection *Dato for indsamling*	ppm lindane	ppm DDE	ppm DDD + DDT
Blue Tit *Blåmejse*	B 1965	9	7	26.VII	trace	4.2	1.9
		1	38	25.V	trace	2.9	0.07
		2	54	4.VI	ND	1.9	0.14
		1	54	10.VII	trace	3.5	0.21
		4	60	4.VI	trace	0.63	0.08
	G 1965	1	16	28.V	0.04	5.5	ND
		4	100	3.VI	0.02	2.3	0.11
	L 1965	2*)	10	4.VII	trace	34	18
		2	17	4.VII	ND	11	0.63
		1**)	27	4.VII	ND	4.5	3.0
	G 1966	3	42	11.VI	0.04	0.37	0.36
	L 1966	1	38	22.VI	0.41	6.4	1.1
Pied Flycatcher *Broget Fluesnapper*	B 1965	1	36	17.VII	ND	3.3	1.3
	L 1965	2	38	19.VI	ND	1.0	0.39
		1	49	27.VI	0.10	11	2.0
		2	53	19.VI	ND	1.4	0.46
		1	55	19.VI	ND	2.7	0.52
	L 1966	2	52	22.VI	0.06	1.2	0.33
Redstart *Rødstjert*	G 1966	1	63	25.VI	0.03	6.8	2.1
Tree Sparrow *Skovspurv*	G 1965	2	6	3.VI	trace	2.3	0.11
		1	6	4.VII	trace	1.0	0.07
		2	13	4.VII	trace	1.3	0.02
		2	22	4.VII	trace	2.4	0.07
		1	35	28.V	0.03	0.83	0.32
		1	54	4.VII	trace	1.8	0.14
		1	69	4.VII	trace	0.86	0.04
		1	76	28.V	0.03	2.6	0.58
		2	89	28.V	0.04	2.6	0.44
		3	89	4.VII	trace	4.8	0.73
	L 1965	1	1	4.VII	trace	1.9	0.46
	G 1966	2	7	25.VI	0.15	0.41	0.55
		3	7	8.VIII	0.10	2.7	0.18
		1	22	11.VI	0.10	2.6	0.58
		4	36	4.VII	0.30	3.6	1.0
		1	37	4.VII	0.50	8.4	2.1
		1*)	41	4.VII	0.20	4.2	2.4
		1	46	4.VI	0.12	0.83	0.11

Tabel 4. Fortsat

Table 4. Continued

Species *Art*	Orchard and Year *Frugtplantage og år*	Number of eggs analysed *Antal æg analyseret*	Box no. *Redekasse nr.*	Date of collection *Dato for indsamling*	ppm lindane	ppm DDE	ppm DDD + DDT
		2*)	65	4.VI	0.10	9.3	1.2
		2	65	11.VI	0.40	22	0.77
		3	65	4.VII	ND	8.5	0.46
		1	69	11.VI	0.35	8.5	2.4
		3	73	11.VI	0.24	9.3	3.5
		1	76	4.VII	0.30	27	0.85
		1	80	1.VIII	0.30	11	3.4
		1	86	1.VIII	0.23	8.8	4.3
		2	89	1.VIII	0.06	4.5	0.88
	L 1966	1	19	14.VII	0.28	1.1	0.25

ND: Not detected. *Ikke påvist.*
trace: *Spor.*
*) Egg smashed. *Æg knust.*
**) Species not verified. *Arten usikker.*

Table 5. Average of the periods m + k + p (days). p = incubation period; for definitions of m and k, see text.

Tabel 5. Gennemsnit af rugetiden (antal dage) i udvidet betydning, se teksten.

Species *Art*	Clutch no. *Kuld nr.*	Year *År*	Orchards *Frugtplantager*			Reference areas *Kontrolområder*	
			B	G	L	Ga	GW
Great Tit	1	1964	12	13	13	14	–
Musvit	1	1965	15	18	14	19	13
	1	1966	13	13	14	–	–
Blue Tit	1	1964	–	–	14	–	–
Blåmejse	1	1965	16	18	14	–	13
	1	1966	13	14	14	–	–
Tree Sparrow	1	1964	–	13.3	–	–	–
Skovspurv	2	1964	–	11.4	–	–	–
	1	1965	–	12.6	–	–	–
	2	1965	–	10.9	–	–	–
	1	1966	–	11.6	–	–	–
	2	1966	–	10.4	–	–	–
	3	1966	–	9.4	–	–	–

than in "normal" unsprayed habitats. Thus two Blue Tit and two Great Tit egg samples collected in GW, in 1965 (at that time no pesticide sprayings had been carried out there) contained only 0.43-1.1 ppm total-DDT and no lindane (BEJER-PETERSEN *et al.* 1972).

When investigating possible correlations between pesticide residues and various aspects of breeding in the following, values for total-DDT are used. Lack of correlation with total-DDT will also indicate lack of correlation with either DDE or DDT+DDD as the concentrations of these two are strongly positively correlated (Spearman rank correlation coefficient, r_s = 0.70, N = 43, P < 0.0005 (SIEGEL 1956) (Great Tit eggs)). Regression analyses are based on the logarithms of the sums (log ppm total-DDT).

Start of egg-laying

The time for start of egg-laying in the Great Tit and the Blue Tit varied from year to year, but the variations were parallel in orchards and reference areas. Differences between the localities were small and most of them apparently can be ascribed to the differing habitats of the localities, in accordance with the tendency of tits breeding in gardens to start egg-laying earlier than tits breeding in woods (LACK 1966).

In the Tree Sparrow the interval between start of laying of successive clutches

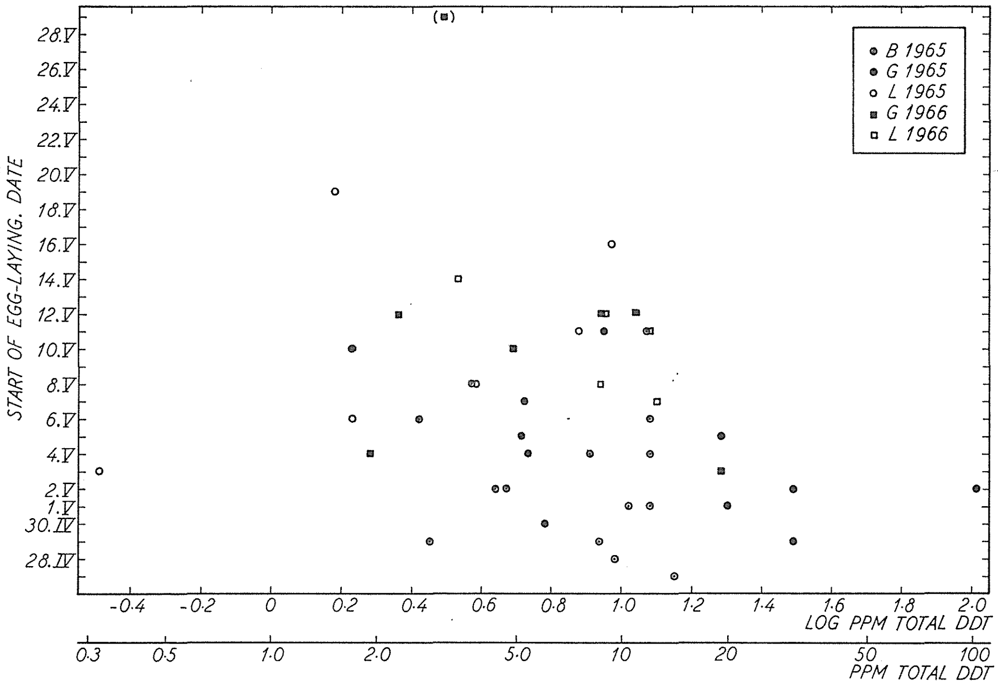

Fig. 1. Relationship between residues of DDT and metabolites in unhatched eggs and time for start of egg-laying in the Great Tit.

Fig. 1. Sammenhæng mellem indholdet af total-DDT i uklækkede æg og tidspunktet for æglægningens begyndelse hos Musvit.

agreed closely with those given by CREUTZ (1949) and SEEL (1968a).

Start of egg-laying is compared with the content of total-DDT in unhatched eggs of the Great Tit in Fig. 1. The mean regression coeficient of the five populations in Fig. 1 is – 1.20, which indicates that *high** content of total-DDT was associated with *early* egg-laying, and that a ten times higher content of total-DDT corresponds to egg-laying one day earlier. The mean regression coefficient is not significantly different from 0 at the 0.05 level, however. (The extremely late record of egg-laying 29.V is not included in the calculations).

In the Tree Sparrow no significant correlations were found between start of egg-laying and content of total-DDT in unhatched eggs (first, second, and third clutches from each year considered separately).

Thus there was no indication of delayed ovulation as found by JEFFERIES (1967) in experiments with Bengalese Finches *(Lonchura striata)* fed on DDT.

Interval between start af egg-laying and hatching of eggs

The date for start of egg-laying can be determined from the number of eggs found at an inspection during the egg-laying period, as one egg is usually laid per day in the species investigated. Thus the egg-laying period is (n – 1) days, where n is the final clutch-size. The date for hatching of most nestlings is determined from their age at later inspections. If there are no irregularities, the incubation period is the interval (i) between start of egg-laying and hatching of nestlings minus (n – 1). This quantity, however, is not always the real incubation period. A number of days (m) are sometimes missed when no eggs are laid, and – although it is unusual in tits and Tree Sparrow (GIBB 1950, SEEL 1968b) – there may be an interval (k) between laying of the last egg and start of incubation. In such cases the quantity i – (n – 1) becomes an expression of m + k + p.

Table 5 present average values of m + k + p. The figures agree well with the duration of the real incubation periods (p) found by GIBB (1950) for tits, viz. 14 days, and by SEEL (1968b) for Tree Sparrows, viz. 11.5. days, with the exception of 1965 when the periods were prolonged for the tits in B and G and in the reference area Ga. In G the calculated values of m + k + p for the Great Tit varied between 13 and 23 days with an additional record of 35 days. An analysis of the Great Tit data reveals that the prolonged periods were partly due to interrupted egg-laying (values of m up to 8 days) and partly due to a delay in start of incubation during daytime.

In 1965 there was a positive correlation ($r_s = 0.672$, $P < 0.02$, Spearman rank correlation coefficient) between residues of total-DDT in unhatched Great Tit eggs and the periods m + k + p, while there was no correlation in 1966 (Fig. 2), and in the Blue Tit in none of the two years.

It is impossible to decide whether the correlation in the Great Tit in 1965 reflects a direct effect of the pesticides, but the possibility exists: In 1965 the number of Great Tits breeding in all areas under observation was higher than found in the other two years. The same applies to the Blue Tit in the orchards. This high density may have caused more frequent territorial encounters and food shortage (as also suggested by low clutch-sizes this year). In this situation of increased stress and/or starvation, the residues of DDT or other pesticides may have resulted in abnormal egg-laying and incubation behaviour through alterations in the hormonal balance as proposed by PEAKALL (1967). Furthermore, the food shortage may have caused depletion of fat reserves, with release of organochlorine pesticides and

*) High and low when discussing pesticide residues in this paper are used as relative terms only.

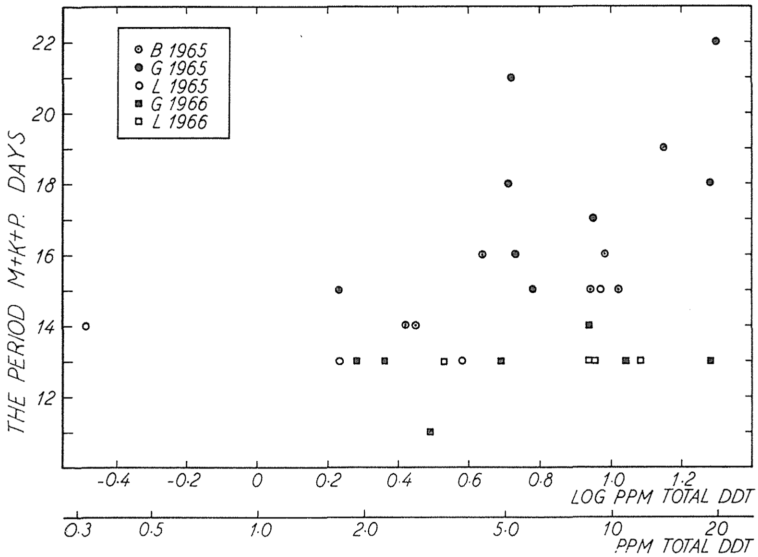

Fig. 2. Relationship between residues of DDT and metabolites in unhatched eggs and length of the period m + k + p in the Great Tit. p = incubation period; for definitions of m and k, see text. Only clutches in which some eggs hatched are included.

Fig. 2. Sammenhæng mellem indholdet af total-DDT i uklækkede æg og rugetidens længde (dage) hos Musvit. Kun kuld, i hvilke nogle af æggene klækkede, er medtaget. Rugetidens længde er her benyttet i en udvidet betydning, se teksten.

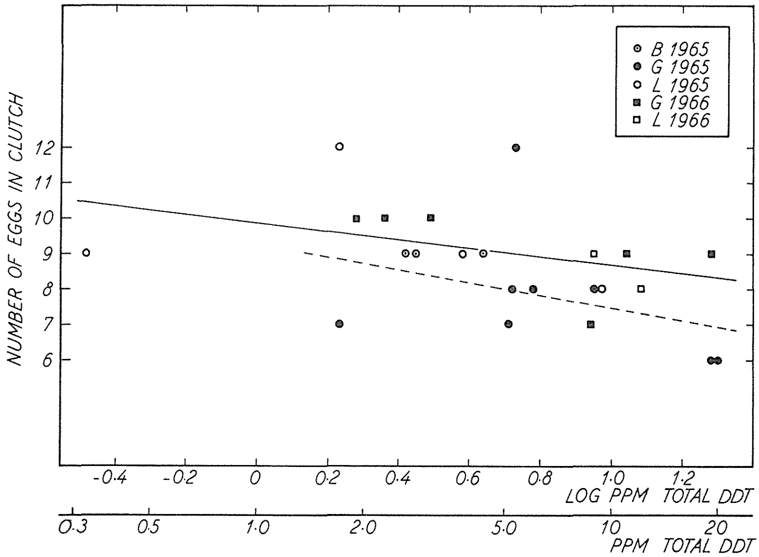

Fig. 3. Relationship between residues of DDT and metabolites in unhatched eggs and clutch-size in the Great Tit. The dashed line represents the regression line for G 1965, the solid line that for the other four populations (B + L 1965, G + L 1966).

Fig. 3. Sammenhæng mellem indholdet af total-DDT i uklækkede æg og kuldstørrelsen hos Musvit. Den stiplede linie angiver regressionslinien for G 1965, den fuldt optrukne regressionslinien for alle de øvrige punkter (B + L 1965, G + L 1966).

greater concentrations in the brain as a result (in accordance with experiments by e. g. BERNARD (1963)).

The observations may also be explained by food shortage alone: The interrupted egg-laying and the delay in start of incubation during daytime may be seen as a response to such food shortage, the nestlings thereby appearing at a later date than with a normal incubation period with a chance that food availability having increased in the meantime. PERRINS (1970) quotes examples of tropical seabirds which cease to lay during periods of food shortage. The reason that incubation periods were not prolonged in L and GW should then be their placing at, respectively in woods, which makes it less likely that food shortage occurred there, while food shortage should have been severe in Ga, also.

Clutch-size

Clutch-sizes in orchards and reference areas agree quite well (Table 6). The variations in the Great Tit probably mostly relates to the varying population densities, clutch-sizes being small when population densities were high and *vice versa* (compare Tables 2 and 6).

Table 6. Clutch-size in orchards and reference areas. Only clutches in which some eggs hatched, and in which clutch-size was accurately known are included. Figures in brackets give number of clutches.

Tabel 6. Kuldstørrelse i frugtplantager og kontrolområder. Kun kuld, i hvilke nogle af æggene klækkede, og hvis størrelse var nøjagtigt kendt, er medtaget. Tallene i parentes angiver antallet af kuld.

Species *Art*	Clutch no. *Kuld nr.*	Year *År*	Orchards *Frugtplantager* B	G	L	Reference areas *Kontrolområder* Ga	M	R
Great Tit	1	1964	11.7(3)	10.2(5)	9.6(9)	9.4(19)	8.8(4)	–
Musvit	1	1965	8.9(12)	7.8(21)	9.1(12)	8.6(12)	–	6.0(10)
	1	1966	9.8(5)	9.2(15)	9.4(5)	–	–	6.7(11)
	2	1964	9.0(1)	7.5(4)	8.0(1)	–	–	–
Blue Tit	1	1964	11.7(3)	12.0(4)	11.0(1)	11.0(1)	10.3(3)	–
Blåmejse	1	1965	10.8(5)	8.5(4)	10.6(5)	–	–	–
	1	1966	10.7(3)	12.5(2)	11.0(2)	–	7.0(1)	9.5(4)
Marsh Tit *Gråmejse*	1	1964-66	all three: 9.0 (3)			all three: 7.0 (3)		
Pied	1	1964	all three: 6.4 (5)			all three: 6.5 (11)		
Flycatcher	1	1965	all three: 6.8 (8)			all three: 5.7 (3)		
Broget	1	1966	all three: 6.0 (6)			all three: 7.0 (5)		
Fluesnapper								
Redstart *Rødstjert*	1	1964-66	all three: 6.7 (3)			all three: 7.0 (5)		
Tree Sparrow	1	1964	all three: 6.3 (4)			–	–	–
	1	1965	all three: 5.2 (14)			–	–	–
Skovspurv	1	1966	all three: 5.6 (8)			–	–	–
	2	1964	all three: 5.0 (1)			–	–	–
	2	1965	all three: 5.7 (11)			–	–	–
	2	1966	all three: 5.8 (9)			–	–	–
	3	1966	all three: 5.3 (8)			–	–	–

The clutch-sizes in the orchards also agree well with those given by various authors for unsprayed areas: BECK (1937), CREUTZ (1949), VON HAARTMAN (1967), LACK (1966), PINOWSKI (1968), SEEL (1968b). The values for the Tree Sparrow are somewhat higher than those given by CREUTZ, PINOWSKI and SEEL *(op. cit.)*. This probably reflects the well known tendency for many bird species to lay greater clutches at more northern latitudes (CODY 1966).

In the Great and the Blue Tit a connection between high residues of total-DDT in unhatched eggs and low clutch-size is indicated, while this is not the case with the Pied Flycatcher and the Tree Sparrow. Thus for the Great Tit the average size of clutches where unhatched eggs contained less than 8.0 ppm total-DDT was 9.2 eggs compared to 7.8 eggs for clutches where residues were higher than 8.0 ppm (data from 1965 and 1966 combined). Fig. 3 shows the Great Tit data (B, G and L 1965 and G and L 1966). When an analysis of variance is performed on all data on clutch-size, only G 1965 differs from the other four populations having a lower mean clutch-size and a greater variance. Regression analyses have been carried out on G 1965 alone and on the four other populations together. The two regression coefficients, –1.80 for G 1965 and –1.19 for the others, do not differ significantly from zero. Nor does the commom slope, $b = -1.24$ ($0.05 < P < 0.1$, HALD 1952, p. 573).

Experiments with DDT fed to gallinaceous birds have shown that high but sublethal doses of insecticides can lower egg-produktion (RUBIN *et al.* 1947, DEWITT 1956, WEIHE 1967). Other experiments, however, failed to show this effect (GENELLY and RUDD 1956, AZEVEDO *et al.* 1965). Neither was egg-production lowered when Mallards *(Anas platyrhynchos)* were fed DDE and DDD (HEATH *et al.* 1969). The widely used fungicides thiram is known to have effected egg-production in experiments (GROLLEAU and BIADDI 1966).

Field studies of populations of the Shag *(Phalacrocorax aristotelis)* (POTTS 1968), the Osprey *(Pandion haliaëtus)* (AMES 1966) and the Herring Gull *(Larus argentatus)* (KEITH 1966) have revealed no connections between pesticide residues and clutch-sizes.

In view of the low pesticide levels in the orchard tit eggs compared to those resulting in the feeding experiments mentioned above, we consider it unlikely that the possible relationship in the orchard tits between low clutch-size and high residues of total-DDT is a causal one. We instead suppose that both pesticide residues and clutch-sizes were correlated with a third common factor, namely food shortage. Females suffering food shortage are likely to produce small clutches (experiments with Pheasants *(Phasianus colchicus)* have shown that egg production and food intake are closely related (GENELLY and RUDD 1956, AZEVEDO *et al.* 1965)), and they may also transfer more pesticide material to the eggs because they contain less fat, hence pesticides occur in higher concentrations.

Hatching success

The percentages of eggs which failed to hatch tended to be higher in the orchards than in the reference areas in the Great and the Blue Tit, but not in the Pied Flycatcher (Table 7). The combined figures for the Great Tit are 7.7 % for the orchards and 4.7 for the reference areas ($0.005 < P < 0.01$, Fisher exact probability test). For the Blue Tit the corresponding figures are 9.5 respectively 5 %.

The values in the reference areas agree well with those given by LACK (1966) for both tit species near Oxford, just under 5 %. GIBB (1950), however, gives somewhat higher values for the same population (6-9 % for the Great, 3-9 % for the Blue Tit). In the Pied Flycatcher and the

Tree Sparrow percentages agree reasonably well with those given by other authors, even though a comparison,in the Tree Sparrow particularly, is hampered by the great variation between the published figures (Pied Flycatcher: CREUTZ (1955), VON HAARTMAN (1951), LACK (1966); Tree Sparrow: CREUTZ (1949), PINOWSKI (1968), SEEL (1968b)).

Connections between high percentages of unhatched eggs in clutches and high contents of total-DDT in these eggs are present in some cases. In the Great Tit there is a highly significant correlation in 1965 (Spearman rank correlation coefficient $r_s = 0.76$, $P < 0.01$, one-tailed test), but no correlation in 1966 (Fig. 4). Likewise in the Tree Sparrow there is an indication of a similar correlation in 1965 (not significant) but no indication in 1966. In the Blue Tit and the Pied Flycatcher there are no indications of correlations.

A number of laboratory experiments with gallinaceous birds fed organochlorine pesticides have revealed that high concentrations in the food are necessary to produce reduced hatchability (RUBIN *et al.* 1947, DEWITT 1955 and 1956, GENELLY and RUDD 1956, AZEVEDO *et al.* 1965, JONES and SUMMERS 1968). WEIHE (1967) from experiments with chicken eggs concluded that the critical level for unaltered reproduction is ca. 200 ppm DDT in yolk. HEATH *et al.* (1969), however, reported strongly reduced hatchabilities of Mallard eggs in experiments where DDE was fed in concentrations of 10 and 40 ppm (dry weight). Feeding with DDD in same concentrations reduced hatchabilities, but less strongly, and feeding with DDT in this concentration range did not result in reduced hatchabilities.

Indication of reduced hatchability in the field following from pesticide contamination has been found in Herring Gull eggs containing 100-300 ppm total-DDT (KEITH

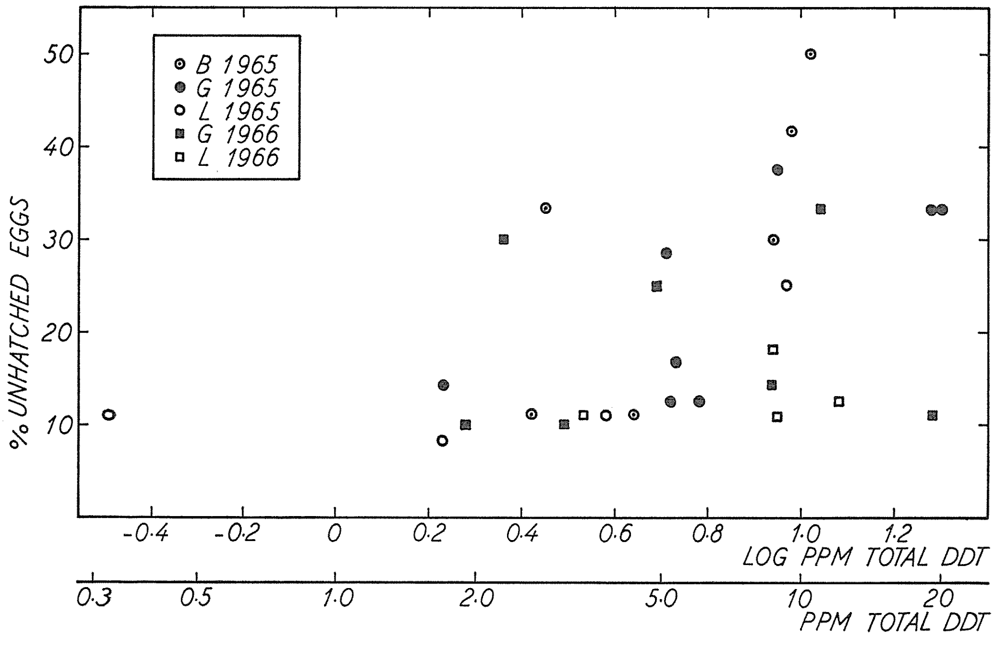

Fig. 4. Relationship between residues of DDT and metabolites in unhatched eggs and percentage of unhatched eggs in the Great Tit.

Fig. 4. Sammenhæng mellem indholdet af total-DDT i uklækkede æg og klækningsprocenten hos Musvit.

1966), but also in Osprey eggs with an average of only 5.1 ppm total-DDT (AMES 1966).

PERSSON and SAMSON (1967) who observed Great Tits in Sweden and MAYER-GROSS (1965) who collected data on Chaffinches *(Fringilla coelebs)* in England found indications of lowered hatching success in insecticide-treated areas, but no egg analyses were carried out.

It was felt by one of us who had previous experience in handling tit eggs that the orchard tit eggs were exceptionally difficult to handle without crashing them, but no systematic recording of cracked eggs were made. Residues of total-DDT in the few damaged eggs that were analysed were rather high (Table 4). The reduced hatchability in the experiments with Mallards fed DDE (HEATH *et al.* 1969) were partly releated to cracking of abnormally thin eggshells. Eggshell cracking has been reported in field studies also (KEITH 1966, RATCLIFFE 1967).

That a correlation between high residues of total-DDT and high percentages of unhatched eggs has been found in the Great Tit in 1965 but not in 1966, despite the fact that residue levels in eggs were similar in both years, indicates, however, that residues of total-DDT has not been the sole reason for reduced hatchability. Other

Table 7. Percentages of eggs which failed to hatch. Only clutches in which some eggs hatched are included. Figures in brackets give number of clutches.

Tabel 7. Procent uklækkede æg. Kun kuld, i hvilke nogle af æggene klækkede, er medtaget. Tallene i parentes angiver antallet af kuld.

Species *Art*	Clutch no. *Kuld nr.*	Year *År*	Orchards *Frugtplantager* B	 G	 L	Reference areas *Kontrolområder* Ga	 M	 R
Great Tit	1	1964	12(10)	7(15)	3(9)	6(24)	6(11)	–
Musvit	1	1965	11(22)	9(33)	3(19)	6(17)	–	0(13)
	1	1966	3(18)	7(25)	6(12)	–	–	1(13)
	2	1964	18(5)	20(5)	0(3)	–	–	–
Blue Tit	1	1964	11(3)	8(4)	45(1)			
Blåmejse	1	1965	12(6)	11(6)	6(6)	1964-66 (Ga + R): 5 (6)		
	1	1966	0(3)	6(6)	9(2)			
Marsh Tit *Gråmejse*	1	1964-66	all three: 11 (3)			all three: 0 (3)		
Pied	1	1964	all three: 6 (5)			all three: 14 (11)		
Flycatcher	1	1965	all three: 10 (11)			all three: 6 (3)		
Broget	1	1966	all three: 5 (10)			all three: 17 (7)		
fluesnapper								
Redstart *Rødstjert*	1	1964-66	all three: 10 (3)			all three: 14 (5)		
Tree Sparrow	1	1964	all three: 32 (4)					
Skovspurv	1	1965	all three: 10 (19)					
	1	1966	all three: 17 (15)					
	2	1964	all three: 20 (4)					
	2	1965	all three: 14 (12)					
	2	1966	all three: 12 (11)					
	3	1966	all three: 17 (9)					

Table 8. Residues of lindane, DDE and DDT + DDD in nestlings.
Tabel 8. Indhold af lindan, DDE og DDT + DDD i unger.

Species *Art*	Orchard and year *Frugtplantage og år*	Number of birds analysed *Antal fugle analyseret*	Box nr. *Redekasse nr.*	Date of collection *Dato for indsamling*	ppm lindane	ppm DDE	ppm DDD + DDT
Great Tit *Musvit*	B 1965	1	14	22.VI	ND	5.0	1.2
		1	72	4.VI	0.17	3.1	0.35
		5	77	22.VI	0.07	2.5	0.23
	G 1965	1	53	3.VI	trace	0.57	0.08
		5	85	28.V	trace	1.2	0.46
	L 1965	1	23	19.VI	ND	1.7	0.58
		1	52	27.VI	ND	0.52	0.29
	B 1966	1*)	7	15.VI	ND	3.5	0.40
		1*)	7	15.VI	ND	3.8	0.62
		1*)	7	15.VI	0.02	4.4	0.76
		1*)	7	15.VI	ND	3.4	0.71
		1*)	7	15.VI	ND	2.6	0.33
		1*)	7	15.VI	ND	2.6	0.65
	G 1966	2	15	4.VI	trace	1.7	0.19
		1	61	4.VI	trace	1.3	0.13
		1	97	31.V	0.06	26	3.7
		1*)	97	15.VI	0.02	3.8	3.4
		1*)	97	15.VI	0.02	3.8	2.8
		1*)	97	15.VI	0.02	3.8	3.4
		1*)	97	15.VI	ND	3.2	2.0
		1*)	97	15.VI	0.02	3.9	3.4
		1*)	97	15.VI	ND	3.7	3.2
		1*)	97	15.VI	0.02	2.8	2.3
		1	100	4.VII	0.05	6.1	2.7
	L 1966	1	1	8.VII	ND	3.1	0.88
		1*)	18	15.VI	0.02	1.3	0.47
		1*)	23	15.VI	0.05	2.1	0.63
		1*)	23	15.VI	0.03	1.6	0.37
		1*)	23	15.VI	0.03	1.4	0.60
		1*)	23	15.VI	0.02	1.6	0.54
		1*)	23	15.VI	0.06	1.5	0.55
		1*)	23	15.VI	0.03	1.8	0.54
		1*)	23	15.VI	ND	1.4	0.44
		1*)	25	11.VI	trace	1.6	0.55
		3	26	22.VI	ND	6.0	1.5
		1*)	40	15.VI	0.01	0.57	0.47
		6*)	42	15.VI	trace	0.73	0.41
		1*)	48	15.VI	0.02	1.3	0.35
		3	50	1.VIII	trace	1.9	0.22

Table 8. Continued

Tabel 8. Fortsat

Species *Art*	Orchard and year *Frugtplantage og år*	Number of birds analysed *Antal fugle analyseret*	Box nr. *Redekasse nr.*	Date of collection *Dato for indsamling*	ppm lindane	ppm DDE	ppm DDD + DDT
		3	53	22.VI	trace	1.4	0.31
		1*)	54	15.VI	trace	1.0	0.31
Blue Tit *Blåmejse*	G 1965	1	16	28.V	0.03	0.72	0.36
		1	16	3.VI	trace	0.33	0.21
		5	52	13.VI	trace	0.18	0.14
	L 1965	1	29	19.VI	0.03	2.4	0.70
		4	29	27.VI	0.04	8.0	1.2
Marsh Tit *Gråmejse*	B 1965	1	56	25.V	ND	7.2	0.47
Pied Flycatcher *Broget fluesnapper*	L 1965	1	5	4.VII	ND	5.2	1.0
		4	24	4.VII	0.01	1.6	0.69
		1	25	27.VI	0.01	1.2	0.63
		1	25	4.VII	0.05	6.6	1.9
		3	55	27.VI	trace	1.3	0.23
	L 1966	5	4	1.VII	ND	7.1	1.6
		3	35	22.VI	ND	4.3	0.88
Tree Sparrow *Skovspurv*	G 1965	1	4	3.VI	ND	0.95	0.20
		1	7	4.VII	0.05	0.48	0.12
		1	13	22.V	1.3	2.2	0.31
		4	44	3.VI	ND	0.60	0.10
		2	54	3.VI	ND	1.8	0.01
		1	80	22.V	ND	2.3	ND
		1	13	1.VIII	trace	1.4	0.20
	G 1966	3	13	15.VIII	0.01	0.84	0.06
		2	37	18.VII	0.02	2.6	2.0
		2	65	4.VI	trace	2.5	0.02

ND: Not detected. *Ikke påvist.*
trace: *Spor.*
*) Killed for analysis. *Aflivet til analyse.*

reasons may be linked with the high population density in 1965 as discussed on page 12.

Residues in nestlings

Table 8 shows that the pattern of occurrence of pesticides in nestlings is the same as found in adult birds and eggs. Total-DDT varies between 0.32 and 30 ppm and lindane between not detectable and 1.3 ppm.

Concentrations of total-DDT tend to be lower in nestlings than in eggs in the tits and the Tree Sparrow (Great Tit: median values 2.1 and ca. 8 ppm in nestlings and eggs respectively, $P < 0.001$, median test (SIEGEL 1956)). The same trend was observed by PERSSON (1971) on residues of total-DDT and PCB in eggs and nestlings of the Whitethroat *(Sylvia communis)*. In the likewise migratory Pied Flycatcher we found the reverse trend.

Table 9. Percentages nestlings dying during nestling period. Included are clutches in which all nestlings died, which may have been caused by parents being killed or nest deserted. Not included are clutches where all nestlings disappeared, probably due to predation. Figures in brackets give numbers of clutches.

Tabel 9. De procentiske ungedødeligheder. Hele kuld, som blev fundet døde, er medtaget, skønt dette kan skyldes, at de er forladte, eller at forældrene er døde. Hele kuld, som forsvandt, er ikke medtaget, da de antagelig er taget af rovdyr. Tallene i parentes angiver antallet af kuld.

Species *Art*	Clutch no. *Kuld nr.*	Year *År*	Orchards *Frugtplantager* B	G	L	Reference areas *Kontrolområder* Ga	M	R
Great Tit *Musvit*	1	1964	25(10)	0(14)	0(8)	32(24)	18(4)	–
	1	1965	22(20)	23(33)	23(19)	52(14)*	–	16(14)
	1	1966	18(18)	23(25)	24(12)	–	–	12(13)
	2	1964	45(3)	33(5)	42(3)	–	–	–
Blue Tit *Blåmejse*	1	1964	0(3)	0(4)	0(1)			
	1	1965	11(6)	59(6)	28(6)	1964-66 all three: 21 (9)		
	1	1966	13(3)	4(5)	0(2)			
Marsh Tit *Gråmejse*	1	1964-66	all three: 25 (3)			all three: 14 (3)		
Pied Flycatcher *Broget Fluesnapper*	1	1964	all three: 0 (5)			all three: 5 (10)		
	1	1965	all three: 21 (11)			all three: 6 (3)		
	1	1966	all three: 24 (10)			all three: 7 (5)		
Redstart *Rødstjert*	1	1964-66	all three: 28 (3)			all three: 3 (5)		
Tree Sparrow *Skovspurv*	1	1964	all three: 0 (4)			–		
	1	1965	all three: 40 (19)			–		
	1	1966	all three: 10 (15)			–		
	2	1964	all three: 25 (4)			–		
	2	1965	all three: 37 (12)			–		
	2	1966	all three: 23 (10)			–		
	3	1966	all three: 32 (8)			–		

* Includes five repeat clutches. *Heriblandt fem omlagte kuld.*

Most of the nestlings analysed had been found dead. There is no difference in the median value of total-DDT of these nestlings and of the nearly full-grown Great Tit nestlings that were killed for analysis; but the two samples differ in respect to age and freshness of the nestlings when collected, which reduces the value of the comparison.

Intra-brood variation among nestlings collected simultaneously is low (coefficients of variation in three Great Tit broods being 14-21 %). In contrast a few cases show that nestlings of differing age from the same brood may differ much in residue levels (by a factor 4 or less) and that levels can both increase and decrease with increasing age. PERSSON (1971) found that residues of total-DDT in Whitethroat nestlings from areas with no sprayings decreased with age.

Nestling mortality

In the Great and the Blue Tit there is no clear difference in nestling mortality between orchards and reference areas (Table 9). Other studies (LACK 1966) have revealed that nestling mortality in the Great Tit varies much with locality, being high (20-45 %) in poor habitats as gardens and pine plantations and low in rich localities as broad-leaved woods (5 %). Thus nestling mortalities in the orchards do not fall outside the range found in other studies. Similar holds for the Blue Tit.

In the Pied Flycatcher, on the contrary, nestling mortality in the orchards was higher than both that in the reference areas and that found in other studies (VON HAARTMAN 1951, CREUTZ 1955, LACK 1966). In L nestling mortality was much higher among pairs breeding in the windbreaks surrounding the orchard than among those breeding in the nearby deciduous wood and at the fringe of it.

The overall Tree Sparrow nestling mortality was 27 %, which lies between that for successful broods (18 %) and that for all broods (41 %, including total failures) given by SEEL (1970) for a British population. PINOWSKI (1968) gives lower values for a Polish population.

Nestling mortality due to pesticides may result from two sources:

1) Those brought to the nestlings with the food, and
2) Those transferred from the mother bird via the egg.

Direct effect of spraying can be left out of account in hole-nesting birds (PRZYGODDA 1955).

Brought with food: A number of facts point at mortality from this cause having been small:

1. With a single exception (30 ppm) residues of total-DDT in nestlings were $\leqslant$ 9 ppm (Table 8). These levels are probably not deadly (see p. 5).

The possibility that some mortality due to the highly toxic organophosphorous pesticides also used in the orchards has occurred and passed undetected cannot be ruled out, however. SCHÖNBECK (1968) observed some mortality among nestlings of tits and flycatchers *(Muscicapa albicollis)* in an Austrian orchard (demeton-methyl, parathion). A number of nestlings from our material were analysed for organophosphorous poisoning by investigating their brain-cholinesterase levels. The results have not been included in Table 8 because the analyses were performed on samples containing nestlings of different broods and species together. All of the analyses showed normal cholinesterase level in brain indicating that organophosphorous poisoning had not occurred to any great extent.

2. Nestlings with tremors probably resulting from pesticide poisoning was observed in one brood only out of a total of ca. 300 inspected weekly. These nestlings (Tree Sparrow, box 44, G 1965) were later found dead and analysis showed very low residues of total-DDT and lindane (Table

Table 10. Breeding results in orchards and reference areas. For the Tree Sparrow results of other investigations are included for comparison. All percentages are relative to numbers of eggs laid and are, therefore , not directly comparable to percentages given in other tables.

Tabel 10. Yngleresultater i frugtplantager og kontrolområder. For Skovspurven er resultater af andre undesøgelser medtaget til sammenligning. Alle procenter er udregnet på grundlag af antallet af lagte æg, og der kan derfor ikke direkte sammenlignes med de procenter, som er anført i andre tabeller.

Species *Art*	Locality *Lokalitet*	Clutch no. *Kuld nr.*	Eggs laid *Antal æg lagt*	Eggs deserted *Forladte æg* (%)	Eggs not hatched *Uklækkede æg* (%)	Eggs hatched *Klækkede æg* (%)	Nestlings dead or disappeared *Døde eller forsvundne unger* (%)	No. *Antal*	Fledged nestlings *Udfløjne unger* (%)	Number of successful broods (one or several fledglings raised) *Antal kuld, hvor mindst en unge blev flyvefærdig*	Average number of fleglings per successful brood *Gennemsnitligt antal flyvefærdige unger pr. kuld (kun kuld, hvor mindst en unge blev flyvefærdig)*
Great Tit *Musvit*	Orchards *Frugtplantager*	1	1603	6	7	88	18	1117	70	156	7.1
		2	117	6	11	83	38	53	45	10	5.3
	Reference areas *Kontrolområder*	1	732	9	5	86	24	452	62	76	5.9
Blue Tit *Blåmejse*	Orchards *Frugtplantager*	1	414	6	9	85	16	287	69	33	8.7
	Reference areas *Kontrolområder*	1	117	0	3	97	21	90	77	10	9.0
Pied Flycatcher *Broget Fluesnapper*	Orchards *Frugtplantager*	1	171	2	7	91	16	127	74	24	5.3
	Reference areas *Kontrolområder*	1	127	5	15	80	5	96	76	19	5.1
Tree Sparrow *Skovspurv*	Orchards *Frugtplantager*	1+2+3	449	7	15	78	24	241	54	67	3.6
	England (Seel 1970)								49		3.8
	Germany (Creutz 1949)								44		3.7
	Poland (Pinowski 1968)								69		4.0

Table 11. Density and reproduction in various Great Tit populations.

Tabel 11. Tæthed og formering i forskellige Musvitbestande.

Locality, habitat and years of investigation *Lokalitet og år for undersøgelsen*	Breeding success (%) *Procenten af lagte æg, som resulterede i flyvefærdige unger* 1st clutches *1. kuld*	2nd clutches *2. kuld*	Pairs per hectare *Par pr. hektar*	Production rate (fledged nestlings) *Gennemsnitligt antal flyvefærdige unger pr. par*	Fledglings per hectare *Flyvefærdige unger pr. hektar*	Source *Kilde*
O.N.O. The Netherlands, mixed woods, 1922-43	56–66	59–67	0.1 – 0.7	3.9 – 14.1 (median 7.4)	0.9 – 5.5 (median 3.25)	Kluijver 1951
Hoenderloo, The Netherlands pine woods, 1922-34	58	65	0.06 – 0.2	6.4 – 13.2 (median 9.5)	0.6 – 1.9 (median 1.0)	Kluijver 1951
Wytham Estate, England, deciduous wood, 1947-49	78–81	69	0.7 – 2.1	8.6	5.6 – 15.6	Gibb 1950
Oxford, England, gardens, 1958-61	?	?	ca. 0.6 – 1.2	4.0[1])	2.4 – 4.8	Perrins 1965
Orchard B, Denmark, 1964-66	65	42	(0.7)[2]) – 2.0	6.5	5.8 – 8.7	This Study *Denne undersøgelse*
Orchard G, Denmark, 1964-66	72	48	(1.0)[2]) – 2.0	6.5	9.8 – 11.6	This Study *Denne undersøgelse*
Orchard L, Denmark, 1964-66	74	47	(1.4)[2]) – 2.4	6.8	10.1 – 16.2	This Study *Denne undersøgelse*
Gammelmosen, Denmark, bog amidst gardens, 1964-65	47	–	1.4 – 1.6	5.3[3])	7.4[3])	This Study *Denne undersøgelse*
Marienborg, Denmark, park, 1964 + 1966	74	–	1.4 – 2.1	6.4	9.8 – 15.4	This Study *Denne undersøgelse*
Rungstedlund, Denmark, park, 1965-66	85	–	2.1 – 2.6	4.8	10.9 – 12.1	This Study *Denne undersøgelse*

1) Calculated from Perrins' figures assuming hatchability = 95%. Maximum value as mortality due to predation was not included in Perrins' figures. *Udregnet efter Perrins' tal, idet klækningsprocenten er sat til 95. Det er en maximumsværdi, da Perrins ikke har medregnet dødelighed forårsaget af rovdyr.*

2) Minimum figures in brackets were probably unusually low. Obtained in 1964 when nestboxes were not put up until 2 months before the breeding season. *Minimumstallene i parentes var sandsynligvis usædvanligt lave. De opnåedes i 1964, da redekasserne først blev sat op 2 måneder før ynglesæsonen.*

3) Based on 1964-figures only as there was heavy human disturbance in 1965. *Udelukkende baseret på tal fra 1964, da der var stærk forstyrrelse i området i 1965.*

8), but earlier the day when the nestlings were found with tremors, spraying with binapacryl had been carried out. It seems likely that the nestlings were poisoned from the intake of this toxic acaricide with food.

3. No difference was found in median values of residues of total-DDT in Great Tit nestlings found dead and those killed for analysis.

4. No correlation was found in the Great Tit between high residues of total-DDT in dead nestlings and high mortalities in the broods from which the nestlings originated.

5. In most cases only a few nestlings of a brood died. When all nestlings died this mostly occurred gradually. Pesticide poisoning would probably result in more or less simultaneous death of the whole brood (Mitchell *et al.* 1953).

We believe that the nestling mortalities found in the orchards have been due to food shortage rather than to poisoning. There can be little doubt that food shortage occurred in the orchards due to the frequent sprayings even though this was not measured. Evidence for food shortage is:

1. The adult birds seldom collected food in the orchards themselves. They never foraged in the fruit-trees but often in the hedgerows in which nestboxes were situated. More often, however, they collected food in grooves or in vegetation around ponds found within or near the orchards; in L the birds mostly foraged in the nearby wood. Tree Sparrows appeared to forage farther away from the orchards than the tits. Pied Flycatchers a few times were seen to catch insects on the open ground between the fruit-trees. A Great Tit searched food in a barley field (all its nestlings later died).

2. Nestling mortalities in general were lower in 1964 than in 1965-66 corresponding with population densities being lower this year, presumably due to nestboxes being first put up about two months before breeding started.

3. In two nestboxes Tree Sparrow nestlings stayed unusually long before they finally died.

On the other hand there are two characteristics of tit broods suffering from food shortage which were not observed in the orchard tits: 1) The nestlings stay longer than usually in the nestboxes before leaving, and 2) Nestling mortality is higher in large than in small broods (Lack 1966).

Via the eggs: When mortality is caused by pesticides transferred from the eggs, it occurs in the newly hatched chicks or nestlings (Azevedo *et al.* 1965, Jones and Summers 1968, Koeman *et al.* 1967), but early mortality can also be characteristic of food shortage (Gibb 1950). Most orchard nestlings which were found dead or disappered, did so early in the nestling period (0-5 days), and we consider food shortage as the main cause.

Furthermore, in the Great Tit a connection exists between *high* residues of total-DDT in unhatched eggs and *low* nestling mortality in the broods from which the eggs originated.

Post-fledging mortality was investigated from recoveries of ringed nestlings of the Great Tit. The few data did not suggest it to be abnormal.

Population dynamics of orchard populations

Table 10 summarizes breeding results in orchards and reference areas for the four principal species studied.

Breeding success (percentage of eggs laid that develop into fledglings) and average number of fledglings per successful brood of first clutches of the Great Tit are both higher in the orchards than found in the reference areas. This suggests that the indicated but not significant correlation between residues of total-DDT and low clutch-size, and the positive correlation between residues of total-DDT and low hatchability found in 1965 but not in 1966, are of minor importance for the breeding results.

For the Blue Tit and the Pied Flycatcher, however, the breeding success and average number of fledglings per successful brood were both lower in the orchards than in reference areas, but we suppose that the populations were able to maintain themselves.

HUBER (1965) recorded a decrease in number of Pied Flycatcher pairs when sprayings were intensified in an orchard, while HENZE (1960) found that this species apparently was unaffected by pesticide sprayings.

In the Tree Sparrow where we have no data from the reference areas, results of some other studies have been included in Table 10 instead. Here the agreement is close too. Both HENZE (1960) and HUBER (1965) found this species to be apparently unaffected by pesticide sprayings. Our own observations and those of HENZE indicate that Tree Sparrows fly longer distances for collecting food than the other species and so are less dependent on food availability in the orchards themselves.

Breeding success and fledglings per successful brood are not sufficient parameters for investigating the possible influences of pesticides on the orchard populations, however. Number of unsuccessful pairs, population density and number of fledglings per hectare have to be considered also. Table 11 compares some of these parameters for various Great Tit populations.

Population density, production rate (= total number of fledglings divided by total number of breeding pairs (KLUIJVER 1951)) and fledglings per hectare differ much between localities, and the orchards apparently are not poorer habitats than the others. Thus none of the reference areas show a higher number of fledglings per hectare than the most productive of the orchards, L. This should mean that pesticide sprayings in the orchards have been without influence on the production of Great Tit fledglings.

We must point out, however, that the population densities in the orchards are probably somewhat too high, because the birds as observed also in other orchard populations (HENZE 1960, HUBER 1965 and SCHÖNBECK 1968) and for tits breeding in pine plantations (LACK 1966) were dependent on areas outside the orchards for feeding. It should, therefore, have been more realistic to include these feeding areas when determining population densities, but their sizes could not be estimated with any certainty.

Decline of tit populations in orchards when sprayings increased are mentioned by HENZE (1960) and HUBER (1965). SCHÖNBECK (1968) who compared bird populations in two orchards in Austria, observed lower density and fewer species in the most intensively sprayed of the two, but differences in the surroundings may have been an important factor. ROBBINS *et al.* (1965) found that application of DDT over a four-year interval on bottom land forest resulted in a 26 % decrease in the breeding bird populations by the fifth spring.

It is clear, however, even if the figures in Table 11 for the Great Tit are somewhat optimistic that the orchard populations are able to maintain themselves. This follows from the fact that production rates, post-fledging and adult mortalities, all fall within the normal ranges of variation.

In the Great Tit there was produced in 1965 6.3 fledglings per completed clutch where unhatched eggs contained less than 8.0 ppm total-DDT compared to 4.2 fledglings per clutch with egg residues higher than 8.0 ppm. The difference is not significant ($0.05 < P < 0.10$, Mann-Whitney U-test, $n_1 = n_2 = 10$, two-tailed). In 1966 the corresponding figures were 7.0 (6 clutches) and 6.2 (5 clutches) fledglings, respectively.

An important reason why direct poisoning occurred to a very low extent probably is that sprayings were carried out regularly throughout the summer period, so that no kind of insects attained to be numerous between the sprayings. The birds, therefore, were not in the habit of foraging among the fruit trees, and they were not attracted to large numbers of halfdead poisoned insects after a spraying.

SUMMARY AND CONCLUSIONS

During the years 1964-1966 the breeding of birds nesting in boxes put up in three Danish orchards was studied. Weekly inspections were carried out, and dead birds and unhatched eggs were analysed for DDT, DDD, DDE, and lindane. Reproductive successs is related to pesticide residues and compared to reproductive success in relatively pesticide-free areas. A total of 360 clutches and broods from the orchards have been followed, and 90 egg samples, 64 nestlings samples and 6 adult birds have been analysed. The main species treated are the Great Tit and the Blue Tit, the Pied Flycatcher and the Tree Sparrow.

The main findings are:

1. DDE was the major pesticide residue found. DDE + DDT + DDD (Total-DDT) ranged 0.32-102 ppm, residues in eggs generally being higher than in nestlings.

2. Dates for start of egg-laying were normal. The period m + k + p (roughly equivalent to the incubation period, see text) was prolonged in the tits in 1965 in two of the orchards and one of the reference areas.

A positive correlation between residues of total-DDT in Great Tit eggs and the length of the interval was found in 1965, but not in 1966. This correlation was not found in the Blue Tits.

3. Clutch-sizes were normal. In the Great Tit the data suggest that small clutches contained more total-DDT than larger clutches, but the regression coefficients did not differ significantly from zero. There were no such tendencies in the other three species.

4. The percentage of tit eggs that failed to hatch was ca. double that normally found, while it was not greater than normal in the Pied Flycatcher and the Tree Sparrow. In 1965, but not in 1966, there was a positive correlation in the Great Tit between high residues of total-DDT in eggs and low hatchability. Such correlations were not indicated for the Blue Tit and the Pied Flycatcher, but in the Tree Sparrow (though not significant) in 1965.

5. Nestling mortalities were high, but not higher than in the reference areas. Food shortage is considered the principal mortality factor. The adult birds depended mainly on areas outside the orchards when colleting food for the nestlings.

6. There is no evidence that poisoning was a mortality factor of importance for nestlings; only one brood of nestlings with signs of intoxication was found.

7. In 1965 there was produced fewer Great Tit fledglings per completed clutch where unhatched eggs contained more than 8.0 ppm total-DDT than from clutches where unhatched eggs contained less than 8.0 ppm total-DDT, viz. 4.2 and 6.3 fledglings respectively. The difference, however, is not significant. In 1966 the corresponding figures were 6.2 and 7.0 fledglings respectively.

8. There is no evidence that adult birds were poisoned. The annual mortality was estimated for the Great Tit in one year; it was not particularly high.

9. The densities of breeding pairs, the production rates and breeding success compare reasonably well with that observed in other studies in probably uncontaminated areas.

10. The main conclusion then is that the major effect of the pesticide sprayings is to reduce food availability for the birds. The possible harmful effect of the pesticides are considered of minor importance. With foraging areas outside the orchards the populations of passerine birds within these are able to maintain themselves.

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DANSK RESUMÉ

Yngleforløb og pesticidindhold i småfuglebestande i danske frugtplantager.

Artiklen redegør for en undersøgelse startet af »Dansk Ornithologisk Forenings Giftkomité« med det formål at undersøge virkningerne af sprøjtninger i frugtplantager på de ynglende fugle. 250 redekasser blev i foråret 1964 sat op i og ved 3 frugtplantager nær Birkerød i Nordsjælland (Bøgebjerggård, Granhøjgård, Lillevang). Redekasserne blev kontrolleret ugentligt og døde fugle og ikke-klækkede æg blev indsamlet og analyseret på Den kgl. Veterinær- og Landbohøjskoles afdeling for farmakologi og toksikologi for deres indhold af pesticider. Undersøgelserne løb i 3 ynglesæsoner, 1964-66. Yngleforløbet i de enkelte kasser blev sammenholdt med pesticidindholdet, og yngleforløbet i frugtplantagerne som helhed blev sammenlignet med forløbet i 3 kontrolområder i Nordsjælland, hvor der også er sat redekasser op (Gammelmosen, Marienborg, Rungstedlund). 360 frugtplantagekuld er fulgt ved ugentlige inspektioner, og 90 ægprøver, 64 ungeprøver og 6 gamle fugle er analyserede. Ialt ynglede der i frugtplantagerne i de 3 år 178 par Musvit, 40 par Blåmejse, 3 par Sortmejse, 4 par Gråmejse, 4 par Rødstjert, 27 par Broget Fluesnapper og 42 par Skovspurv. De vigtigste resultater er:

1. DDE (et nedbrydningsprodukt af DDT) var det stof, der fandtes i størst mængde. DDT + DDE + DDD (total-DDT) varierede mellem 0,32 og 102 ppm (= parts per million = milliontedele beregnet vægtmæssigt). Der var gennemgående mere i æg end i unger. Der var kun ganske lidt lindan i prøverne (under 0,50 ppm i alle undtagen 1).

2. Æglægningen startede til normal tid. Rugetiden, der her er beregnet, så den også omfatter eventuelle oversprungne dage under æglægningen og dage mellem æglægningen og rugningens påbegyndelse, var forlænget hos mejserne i 1965. Hos Musvitten var lang rugetid og højt indhold af total-DDT i uklækkede æg positivt korrelerede i 1965, men ikke i 1966.

3. Kuldstørrelsen var normal. Hos Musvitten tyder tallene umiddelbart på, at små kuld indeholdt mere total-DDT end store kuld, men statistisk kunne denne korrelation ikke påvises. Hos Blåmejse, Broget Fluesnapper og Skovspurv sås denne tendens ikke.

4. Procentdelen af uklækkede mejseæg var ca. dobbelt så stor som normalt, mens den ikke var unormalt stor hos Broget Fluesnapper og Skovspurv. I 1965, men ikke i 1966, var der hos Musvit en positiv korrelation mellem højt indhold af total-DDT i uklækkede æg og lav klækning. En tilsvarende korrelation er antydet hos Skovspurv i 1965, mens der ingen antydninger er hos Blåmejse og Broget Fluesnapper.

5. Ungedødeligheden var høj, men ikke højere end i kontrolområderne. Fødemangel var formo-

dentlig den vigtigste dødsårsag. De gamle fugle var i vid udstrækning afhængige af områder udenfor frugtplantagerne, når de samlede føde til ungerne.

6. Forgiftning synes ikke at have været en dødsårsag af betydning for ungerne. Kun i ét tilfælde kunne årsagen til døden af et kuld unger med sandsynlighed henføres til forgiftning.

7. I 1965 blev der produceret færre flyvefærdige unger pr. fuldlagt musvitkuld, hvor uklækkede æg indeholdt mere end 8 ppm total-DDT, sammenlignet med kuld, hvor uklækkede æg indeholdt mindre end 8 ppm, nemlig henholdsvis 4,2 og 6,3 unger. Denne forskel er dog ikke signifikant. I 1966 var de tilsvarende tal henholdsvis 6,2 og 7,0. Vi formoder, at tendensen til ringere produktion i 1965 ikke er en direkte virkning af pesticiderne, men snarere hænger sammen med fødeknaphed forårsaget af den høje tæthed af ynglepar dette år. Sammenhængen er antagelig den, at fugle, der lider af fødemangel, vil producere færre flyvefærdige unger og også overføre mere pesticid til æggene, fordi deres fedtreserver er mindre, hvilket giver højere koncentrationer af pesticider også i æggeblommerne.

8. Der blev ikke fundet tegn på, at gamle fugle blev forgiftet. Den årlige dødelighed for Musvitten blev skønnet et år. Den var ikke påfaldende høj.

9. Musvitpar pr. ha, procenten af lagte æg, som resulterede i flyvefærdige unger, gennemsnitligt antal flyvefærdige unger pr. par og flyvefærdige unger pr. ha, alle disse størrelser svarer godt til, hvad der er fundet for kontrolområderne og i andre undersøgelser i formentlig usprøjtede områder.

10. Hovedkonklusionen er, at sprøjtningernes væsentligste indflydelse på fuglebestandene formodentlig er at reducere fødemængden. De direkte skadelige virkninger på fuglene må anses for mindre betydningsfulde. Med fødeområder udenfor frugtplantagerne er småfuglene i stand til at yngle med et tilfredsstillende resultat, således at bestanden kan opretholdes.

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On the Effects of Insecticide Sprayings in Forests on Birds Living in Nest Boxes

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(Med et dansk resumé: Om virkningen af kemisk insektbekæmpelse i skov på fugle i ynglende redekasser.)

INTRODUCTION

Insecticidal sprayings in Danish forestry concern very small areas (BEJER-PETERSEN 1968. They are – and to some degree must be – a controversial matter because other fauna elements than the pest insect may be harmed. The financial points of view of the forest management and the aesthetic points of view of e. g. the amateur ornithologist have little in common. The investigations described in this paper were designed to bring forward some facts in the discussion. Another group has carried out similar investigations in Danish orchards (DYCK et al. 1972).