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

By
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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).

METHODS

Locality, nest boxes and inspections
Three large and four small plots were established and furnished with nest boxes by Schwegler (Bruns 1954) in early March 1964 in Grib Forest about 60 km north of Copenhagen. The distance between plots was from 300 to 2400 m. They were chosen in coniferous forest, as most actual control operations take place in this type of forest. The nest boxes were placed at a height of 1.5 m (young spruce) up to 4 m (old spruce).

The size of the plots and the number of nest boxes are shown in Table 1. To ensure nesting possibilities a surplus of boxes was set up. The nest boxes were inspected and cleaned during the winter and early spring. Missing or fallen boxes were replaced if possible. 3-5 inspections were made during the breeding season. During spraying years one inspection was made one or two days before spraying, and at least two inspections took place the following week. Numbers of eggs and nestlings were noted; dead nestlings were removed for analysis, and nestlings of appropriate size were ringed. However, if a parent bird was in the box it was not turned out, and the above mentioned information had to be obtained on a later occasion.

Sprayings
Sprayings were carried out in 1965 and 1967 including a zone of 30 m outside the nest boxes. The areas, insecticides and dosages involved are shown in Table 1. Data from the years 1966, 1968 and partly 1964 serve for comparison.

Spraying was carried out by helicopter in dry weather with little wind (4.6.1965: SSW 1-2 m/sec., and 3.6.1967: W 1-3 m/sec).

Flying height was a few meters above the canopy.

For the sake of experiment *the spraying dates were chosen with the deliberate intention of harming the birds as much a possible.* Sprayings were, therefore, carried out when the tit eggs had just hatched.

Some comparison criteria and definitions used

a. *Breeding success:* the youngs flying as a percentage of the number of eggs laid.

b. *Nestling loss after spraying:* nestlings died or disappeared after the last inspection before spraying.

c. *Percentage nestling loss after spraying:* b as a percentage of the total number of eggs hatched.

d. *Distribution of nestling loss after spraying:* the number of broods with 1-2 or more nestlings lost.

Of these criteria a gives an overall survey disregarding the spraying date, while b and c, for tits, more accurately measure losses after spraying. *F. hypoleuca* breeds later than tits, and little or no loss of *hypoleuca* nestlings occurred before spraying.

Statistical evaluation of a-c is hampered by the fact that the single individual is used as the basal unit. As parent birds feeding one nestling with poisoned food usually also feed others in the brood at the same time, the brood, and not the individual, ought to be the basal unit. This is provided by criterion d, but, at the same time, numbers involved in comparisons are strongly reduced and few tests made possible. In the following some tests have been made using criteria a-c. They should be read with the above comments in mind.

For the sake of comparison between years, a fictive date was fixed for the years 1964, 1966 and 1968 (i. e. the date when the nestlings were of an age similar to that of nestlings when spraying was carried out in 1965 and 1967).

In all evaluations some disturbed broods (especially plot F 1965) and some unidentified broods (non-spraying years) have been omitted.

Chemical analysis
During 1965 and 1967 eggs and nestlings were collected for estimation of residues of parathion, lindane (γ 1,2,3,4,5,6–hexachlorocyclohexane) DDT (1,1,1–trichloro–2,2–bis (p–chlorophenyl)–ethane), DDE (1,1–dichloro–2,2–bis (p–chlorophenyl)–ethylene) and DDD (1,1–dichloro–2,2–bis (p–chlorophenyl)–ethane).

In addition the cholinesterase activity in brains from some nestlings was estimated.

Material
The analysis of the eggs was 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.

Using the skinned head and body as raw material the insecticide content of the nestlings was analysed. Single organs could not be dissected due to putrefaction or to drying out.

Whenever reference is made to more than one individual the figures in Tables 3, 5, 7 and 9 refer to the analysis of pooled eggs or nestlings from the boxes in question.

Parathion
A quantitative determination as described by Karlog (1957) was carried out. However, the

Table 1. Data on Plots, Box Numbers and Sprayings.

Tabel 1. Data vedr. parceller, antal redekasser og sprøjtninger.

Plot *(Parcel)*	A	C	F	H	K	N	O
Norway Spruce *(Rødgran)* Age in 1964, years *(alder 1964, år)*	19–63	21–46	25–48	14	15	11	13
Area with nest boxes *(areal med redeks.)*, ha	14.43	12.06	11.50	1.27	3.43	2.30	2.33
Area sprayed *(areal sprøjtet)*, ha	22.08	–	19.95	2.47	5.71	3.22	–
Nest boxes present, No. *(antal redeks. tilstede)* 1964-1968	124–121	124–119	125–121	25	35	20	20
Insecticide *(insecticid)* 1965	Parathion	None	Malathion	DDT	DDT	Malathion	None
Dosage *(dosering)* g/ha	350	–	900	1000	1000	900	–
Insecticide *(insecticid)* 1967	Malathion	–	Lindane	Malathion	Lindane	DDT	–
Dosage *(dosering)* g/ha	900	–	320	900	320	1000	–

Table 2. Broods of *F. hypoleuca* (h) and first broods of *P. major* (m) and *P. ater* (a).

Tabel 2. Kuld af Br. Fluesnapper (h) og første kuld af Musvit (m) og Sortmejse (a).

	1964			1965			1966			1967			1968		
Plot	m	a	h	m	a	h	m	a	h	m	a	h	m	a	h
A	7	4	0	27	11	3	10	7	6	7	10	4	12	5	6
C	6	4	2	26	11	0	9	8	6	9	8	11	11	8	15
F	4	4	11	29[1]	7	10[2]	10	8	18	10	8	17	12	7	25
H	6	0	2	12	2	2	3	1	2	4	2	1	5	1	1
K	5	0	0	11	5	1	2	1	0	5	1	1	5	2	2
N	3	0	0	12	0	0	4	1	0	2	0	0	4	0	0
O	4	0	0	15	0	1	0	0	0	7	1	0	4	0	0
Total	35	12	15	132	36	17	38	26	32	44	30	34	53	23	49

[1]) including 8 broods disturbed and relaid *(medregnet 8 forstyrrede og omlagte kuld).*
[2]) including 3 broods disturbed and relaid *(medregnet 3 forstyrrede og omlagte kuld).*

method for determining total p-nitrophenol was modified as described by ANDERSEN & KARLOG (1963). The concentrations are given in ppm (= μg p-nitrophenol calculated as parathion/g wet body weight).

Lindane, DDT and the metabolites DDE and DDD

Cleaning-up and quantitative determination of the insecticides were identical to those described by DYCK et al. (1972).

As DDT may also be converted to DDD post mortem (STICKEL et al. 1966), and as the material was stored for months before the analysis was made, the figures mentioned are the sum of DDD and DDT, calculated as DDT. The concentrations are given in ppm (= μg insecticide/g wet body weight).

Cholinesterase activity

The cholinesterase activity in brain-tissue was measured by the WARBURG manometric method, as modified by AUGUSTINSSON (1948). The activities are given in μl CO_2 per 30 min. per 100 mg brain-tissue.

RESULTS

General remarks on the birds breeding in the nest boxes

From 1964 to 1968 eight bird species bred in the boxes. These were (No. of broods indicated): Wryneck *(Jynx torquilla)* 3; Great Tit *(Parus major)* 357; Blue Tit *(P. caeruleus)* 39; Coal Tit *(P. ater)* 178; Marsh Tit *(P. palustris)* 2; Nuthatch *(Sitta europaea)* 1; Redstart *(Phoenicurus phoenicurus)* 1, and Pied Flycatcher *(Ficedula hypoleuca)* 147.

For comparison of breeding data between plots and from year to year only those on *F. hypoleuca* and on the first broods of *P. major* (302) and *P. ater* (127) are suited (Table 2). Other numbers were far too small from each plot. As is well known from elsewhere (KLUIJVER 1951), second broods of the tits fluctuate markedly from year to year. Egg numbers were also lower and breeding success varied more than in the first broods.

Breeding was initiated almost simultaneously in all plots, though in 1965 *P. major* was nearly one week later in plot F than in the other plots but this may be due to disturbance. Egg numbers varied somewhat between years and between plots. In *Parus major*, for example, the average for plots was 7.5-8.5 in 1965 against 8.5-10.5 in 1967.

The concentrations of lindane, DDE and DDT in eggs are given in Table 3.

In 1965 the tit broods were most numerous – but with the lowest mean clutch – of all years.

Parus major

Breeding success

The breeding success (Table 4) seems to be lower on both sprayed and unsprayed plots in the spraying year 1965 as compared with the non-spraying years 1964, 1966 and 1968. In the spraying year 1967, however, this difference was not ascertained.

In 1965 the breeding success is particularly low (49%) on one DDT-treated plot (K) when compared with the unsprayed comparison plots (C and O) with a breeding success of 87 and 90% respectively. In the other plot sprayed with DDT (H) and in the plot sprayed with parathion (A) the breeding success is 84% in both, a little lower than on the untreated plots. In the plots treated with malathion (F and N) breeding success is of the same magnitude as in the non-sprayed plots.

When comparing the quotients of fledgelings/eggs, only one DDT plot (K) shows a significantly lower breeding success than the untreated plots (χ^2, Yates corr.) in the same year ($0.02 < p < 0.05$). Furthermore, the deficit in the percentage breeding success in 1965, as compared with the average of 1964 and 1966, is significantly higher in this DDT plot than the corresponding deficit in the untreated plot C in the same year ($0.01 > p > 0.001$). As no broods were found in the untreated plot O in 1966 a comparison with this plot is not possible. In 1967 the breeding success in the sprayed plots (lindane, malathion and DDT) is somewhat higher than on the untreated plots.

Nestlings dead or disappeared after spraying

Nestling losses were high in both sprayed and unsprayed plots in 1965 when compared with 1964 and 1966. In 1967 losses

Table 3. Concentration of lindane, DDE and DDD + DDT in eggs.

Tabel 3. Koncentration af lindan, DDE og DDD + DDT i æg.

Species *Art*	Year *År*	Plot *Parcel*	Number of eggs analysed *Antal æg analyseret*	ppm lindane	ppm DDE	ppm DDD + DDT
Parus major	1965	K	2	n. d.	0.40	0.72
		K	8	n. d.	0.58	0.04
	1967	Strødam[1])	4	n. d.	1.4	0.02
		Strødam[1])	4	n. d.	1.3	0.01
		Strødam[1])	3	n. d.	0.86	0.03
		A	2	n. d.	1.3	0.05
		A	3	n. d.	1.7	0.05
Parus ater	1965	A	1	trace	0.41	0.02
	1967	A	3	n. d.	2.9	0.13
Parus caeruleus	1965	H	2	n. d.	0.38	0.05
		O	1	n. d.	0.41	0.02
	1967	C	4	0.07	0.94	0.15
		C	3	0.06	0.67	0.13

n. d.: not detected. *(Ikke påvist).*

1) Each egg from Strødam represents one brood. *(Hvert æg fra Strødam repræsenterer 1 kuld).*

Table 4. *Parus major.* 1) Egg number, 2) Breeding success %, 3) Nestling loss after spraying No., and 4) Percentage.

Tabel 4. Parus major. 1) *Ægantal,* 2) *ynglesucces %* 3) *ungetab efter sprøjtning, antal og* 4) *%.*

Years *År*	1964				1965				1966				1967				1968			
Plots *Parceller*	1)	2)	3)	4)	1)	2)	3)	4)	1)	2)	3)	4)	1)	2)	3)	4)	1)	2)	3)	4)
A	73	100	0	0	211	84	17	9	89	99	0	0	62	98	0	0	104	77	0	0
C	68	97	0	0	204	87	18	10	88	98	1	1	90	88	10	11	67	94	0	0
F	43	100	0	0	165	88	7	4	81	89	8	10	102	93	1	1	108	86	3	3
H	62	97	0	0	95	84	9	10	29	97	0	0	36	100	0	0	44	91	1	2
K	52	100	0	0	87	49	33	43	19	100	0	0	40	95	2	5	49	90	0	0
N	34	97	0	0	92	89	7	8	47	98	0	0	21	100	0	0	35	97	0	0
O	41	98	1	2	105	90	7	7	0	–	–	–	65	88	8	12	37	97	0	0

are very small, especially in the sprayed plots.

In 1965 the quotient of nestlings lost to total number of nestlings is significantly higher in one of the two plots sprayed with DDT (K) as against the untreated plots in the same year ($p < 0.001$).

The increased mortality in plot K in 1965 relative to the average of 1964 and 1966 does not deviate significantly from the increased mortality in the untreated plot (C) in the same year. The reciprocal percentage i. e. fledgelings as a percentage of all nestlings is, however, significantly lower in the DDT plot K owing to higher figures involved ($0.02 < p < 0.05$).

In this context it should also be mentioned, that the comparisons between percentages given are extremely rough and based on varying numbers. The figures should, therefore, be taken with great reservations.

In the other DDT-sprayed plot in 1965 (H) as well as in the plots sprayed with

Table 5. Residues of parathion, lindane, DDE and DDD+DDT in *Parus major* nestlings.

Tabel 5. Indhold af parathion, lindan, DDE og DDD+DDT i Musvitunger.

Treatment *Behandling*	Plot *Parcel*	Year *År*	Number of nestlings analysed *Antal unger analyseret*	Box No. *Redekasse nr.*	ppm Parathion	ppm Lindane	ppm DDE	ppm DDD+DDT
Parathion	A	1965	1	32	<0.04	–	–	–
			8	65	3.1	–	–	–
			1	98	n. d.	–	–	–
Malathion	H	1967	1*	11	–	n. d.	0.28	0.04
Lindane	K	1967	1*	11	–	n. d.	0.28	0.08
			1*	15	–	trace	0.21	0.11
DDT	H	1965	2	18	–	n. d.	0.22	0.60
			1	19	–	0.07	0.37	2.8
	K	1965	3	3	–	–	–	0.17
			5	4	–	–	–	0.60
			12	14	–	–	–	0.10
			2	33	–	–	–	0.47
Not treated	C	1965	2	25	–	n. d.	0.26	0.18
			2	46	–	n. d.	0.34	0.16
			1	110	–	n. d.	0.25	0.08
	O	1967	1*	11	–	n. d.	0.13	0.03
			1	2	–	n. d.	0.15	n. d.
			1	2	–	n. d.	0.24	n. d.
			1	2	–	n. d.	0.18	n. d.
			1	2	–	n. d.	0.24	n. d.
			1	2	–	n. d.	0.22	n. d.
			1	2	–	n. d.	0.19	n. d.
			1	2	–	n. d.	0.20	0.07
			1	2	–	n. d.	0.19	0.04

n. d.: not detected. *Ikke påvist.*
–: no analysis made. *Ikke analyseret.*
*: killed for analysis. *Aflivet til analyse.*

malathion and parathion that year the losses are of the same magnitude as on the untreated plots.

In 1967 the loss seems to be greater in the untreated plots than in the treated ones.

The distribution of nestling losses after spraying

In the spraying years the only plot with a significantly higher loss per brood than on the untreated plots is DDT-area K in 1965. (Proportion of broods with loss of more than three nestlings $0.001 < p < 0.01$). In the untreated plots in 1965 (as a total) the proportion of broods with losses is furthermore significantly higher than in the total for every other plot in all other years ($p < 0.01$). In fact, in 1965 12 of a total of 40 comparable broods on the untreated plots suffered losses while in all other plots and in all other years only 13 of a total of 159 broods had losses. This stresses the general high mortality level of 1965.

Analysis of nestlings of Parus major

The results of the analysis of the content of parathion, lindane, DDE and DDD + DDT in *Parus major* nestlings are given in Table 5.

Parus ater

Breeding success

The breeding success is shown in Table 6. Similar to the results for *Parus major*, the breeding success appears to be generally lower in 1965 than in the other years reviewed.

In 1965 the breeding success was 65% and 59% respectively on the parathion and malathion plots (A and F), and 88% on the untreated plot (C), but the ratios fledgelings/total number of eggs are not significantly different. On the DDT plot (K) the breeding success (97%) is higher. This is quite a different situation from that of *Parus major*.

When the deficit in percentage breeding successs in 1965 in relation to the average of 1964 and 1966 in the plots treated with parathion (A) and with malathion (F) is compared with the corresponding deficit in the untreated plot (C), no significant deviations are found.

In 1967 the breeding success in the major malathion plot (A) is 90%, not significantly lower than on the untreated plots (97%, 100%). In the small malathion plot (H) and in the lindane sprayed plot (F), the breeding success is, however, 100% and 96% respectively.

Nestlings dead or disappeared after spraying

Similar to the loss of *Parus major* nestlings, the loss of *Parus ater* nestlings is generally greater in 1965 than in the other years under review.

In 1965 the losses were 31 and 26% respectively in the parathion and malathion plots (A, F), but only 10% in the untreated plot (C), and in DDT plot K it was as low as 3%. In the parathion plot the losses, measured as the ratio nestlings lost after spraying/total number of nestlings, are significantly higher than in the reference area ($0.001 < p < 0.01$). In the malathion area the significance level is not reached ($0.05 < p < 0.10$). Comparison of losses in 1965 to the average of 1964 plus 1966 reveals no significant deviation between parathion, malathion and reference (C) plots, neither when compared as percentages loss nor as percentages of nestlings flown. In 1967 the losses amounted to between 0 and 2% only both for the untreated plots and for the plots treated with lindane and malathion. There were no broods in the plot sprayed with DDT.

The distribution of nestling losses after spraying

In the spraying year 1965 the ratio of broods with high losses to broods with small or no losses is somewhat greater in the parathion and malathion area than in the unsprayed plot. These devations are, however, not on significance level. Similarly, the distribution of losses in 1967 does not imply differences on significance level.

In the untreated plot in 1965 the ratio of broods with loss to broods without loss is significantly ($0.01 < p < 0.02$) higher than for the sum of all plots in all other years (similar to *Parus major).*

Analysis of nestlings of Parus ater

The results of the analysis of the content of parathion, lindane, DDE and DDD+DDT in *Parus ater* nestlings are given in Table 7.

Table 6. *Parus ater.* 1) Egg number, 2) Breeding success % 3) Nestling loss after spraying No., and 4) Percentage.

Tabel 6. Parus ater. 1) *Ægantal,* 2) *ynglesucces %* 3) *ungetab efter sprøjtning, antal og* 4) *%.*

Years *År*	1964				1965				1966				1967				1968			
Plots *Parceller*	1)	2)	3)	4)	1)	2)	3)	4)	1)	2)	3)	4)	1)	2)	3)	4)	1)	2)	3)	4)
A	37	95	0	0	74	65	23	31	51	100	0	0	92	90	2	2	50	94	0	0
C	38	97	0	0	84	88	9	10	80	95	0	0	70	97	0	0	52	94	0	0
F	37	95	0	0	49	59	10	26	74	93	4	5	54	96	1	2	62	90	2	3
H	17	94	0	0	0	–	–	–	11	100	0	0	10	100	0	0	11	82	0	0
K	0	–	–	–	33	97	1	3	0	–	–	–	0	–	–	–	17	100	0	0
N	0	–	–	–	0	–	–	–	5	20	0	0	0	–	–	–	0	–	–	–
O	0	–	–	–	0	–	–	–	0	–	–	–	10	100	0	0	0	–	–	–

Table 7. Residues of parathion, lindane, DDE and DDD+DDT in *Parus ater* nestlings.

Tabel 7. Indhold af parathion, lindan, DDE og DDD+DDT i Sortmejseunger.

Treatment *Behandling*	Plot *Parcel*	Year *År*	Number of nestlings analysed *Antal unger analyseret*	Box No. *Redekasse nr.*	ppm Parathion	ppm Lindane	ppm DDE	ppm DDD+DDT
Parathion	A	1965	4	18	11	–	–	–
			1	40	<0.04	–	–	–
			4	104	4.9	–	–	–
			3	106		–	–	–
Lindane	F	1967	1*	14**	–	0.15	0.19	0.09
			2	26**	–	n. d.	0.54	0.06
			1*	42**	–	0.13	0.12	0.04
			1*	96**	–	0.11	0.13	0.08
	K	1967	1*	17**	–	0.14	0.38	0.33
Not treated	C	1967	1*	59**	–	0.01	0.20	n. d.

n. d.: not detected. *Ikke påvist.* –: no analysis made. *Ikke analyseret.*
*: killed for analysis. *Aflivet til analyse.* **: second brood. *Andet kuld.*

Ficedula hypoleuca

As the sprayings took place at a time when the *Pied flycatcher* mainly had eggs while the tits had small youngs, the effect on *flycatcher* nestlings was expected beforehand to be lower than on tit nestlings. *Flycatcher* breeding success is on the whole (Table 8) more varied and lower than that of the tits. Besides this the average clutch size and the number of broods per plot is generally lower. The possibilities of evaluating the effect of the sprayings are correspondingly small.

Breeding success

For 1965 statistical treatment is invalidated by the fact, that there was only one brood of flycatchers in a single untreated plot.

In 1965 the breeding success was 50% in the parathion plot (A) and 72% in the malathion plot (F) while it was 100% in the small untreated plot (O) and in the DDT treated plots (H and K).

In 1967 the breeding success was 77% in the untreated plot (C) and 78% in the malathion plot (A), but high in the small malathion plot (H) and in both lindane plots (F, K). No significant deviations can be ascertained.

Nestlings dead or disappeared after spraying

In 1965 nestling loss was high in the parathion and malathion plots (36 and 28% resp.) although no higher than in some plots in the non-spraying year of 1968. For 1965 neither the relation nestlings lost/total nestlings nor the relation fledgelings/total nestlings – which includes higher figures – show significant deviations between plots.

In 1967 nestling loss was 22% in the malathion treated plot (A) and 16% in the untreated comparison (C); however, the deviation is not significant. The small malathion plot (H) and the two lindane treated plots had less than 5% loss.

The increased loss of *flycatchers* in the malathion treated plot (A) in 1967 compared with the average from 1966 and 1968 deviates significantly from the corresponding change in loss in the untreated plot C ($p < 0.001$). This is, however, partly because of the high percentage loss in the untreated plots both in 1966 and 1968.

The distribution of nestling loss

Among the *flycatchers* whole clutches are

Table 8. *Ficedula hypoleuca.* 1) Egg number, 2) Breeding success % 3) Nestling loss after spraying, No., and 4) Percentage.

Tabel 8. Ficedula hypoleuca. 1) *Ægantal,* 2) *ynglesucces %* 3) *ungetab efter sprøjtning, antal og* 4) *%.*

Years *År*	1964				1965				1966				1967				1968			
Plots *Parceller*	1)	2)	3)	4)	1)	2)	3)	4)	1)	2)	3)	4)	1)	2)	3)	4)	1)	2)	3)	4)
A	0	–	–	–	18	50	5	36	35	89	3	9	27	78	6	22	39	92	0	0
C	13	100	0	0	0	–	–	–	32	81	6	19	70	77	10	16	90	64	28	33
F	66	94	3	5	46	72	13	28	116	88	13	11	105	94	4	4	160	56	51	36
H	14	86	0	0	7	100	0	0	7	100	0	0	6	100	0	0	7	86	1	14
K	0	–	–	–	6	100	0	0	0	–	–	–	7	100	0	0	13	69	4	31
N	0	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–	0	–	–	–
O	0	–	–	–	6	100	0	0	0	–	–	–	0	–	–	–	0	–	–	–

rather often lost. Statistical treatment of the distribution of nestling loss to broods reveals only one deviation of importance: numbers of broods with losses are higher in the non-spraying year 1968 than the sum for all other years ($0.001 < p < 0.01$). 1968 was the year with the highest number of *flycatcher* broods and corresponding to 1965 for the tits.

Analysis of nestlings of Ficedula hypoleuca
The results of the analysis for the content of parathion, lindane, DDE and DDD+DDT in *Ficedula hypoleuca* nestlings are given in Table 9.

Trends for bird populations after spraying

The numbers of first broods for tits and numbers of broods among flycatcher (Figs. 1, 2) are a measure of the spring population because a considerable surplus of empty nest boxes were always found in the experimental plots. For *Parus major* some data are also given from the orchard plots (1964-66).

Parus major. In 1965 the highest number of broods was recorded in all plots. The reduction from 1965 to 1966 in each of the groups: orchards, large forest plots and small forest plots is almost parallel within each group, but the reduction relative to 1965 is larger in the order mentioned. The quotient broods 1966/broods 1965 is in each group 59/83 – 29/82 – 9/50 respectively. The quotient for the orchards is significantly higher than for the forest groups (compared to the large forest plots (χ^2) $0.01 < p < 0.02$). From 1966 to 1968 only small and insignificant changes between the forest plots were recorded.

Parus ater. A maximum in 1965 is much less evident than for *Parus major*. One plot (malathion, F) even had a rise in numbers from 1965 to 1966. Differences between

Table 9. Residues of parathion, lindane, DDE and DDD+DDT in *Ficedula hypoleuca* nestlings.
Tabel 9. Indhold af parathion, lindan, DDE og DDD+DDT i Fluesnapperunger.

Treatment *Behandling*	Plot *Parcel*	Year *År*	Number of nestlings analysed *Antal unger analyseret*	Box No. *Redekasse nr.*	ppm Parathion	ppm Lindane	ppm DDE	ppm DDD+DDT
Parathion	A	1965	1	107	n. d.	–	–	–
			4	107	n. d.	–	–	–
Malathion	A	1967	1	51	–	0.30	0.30	0.03
			1	51	–	0.02	0.36	0.12
			1	51	–	0.12	0.44	0.17
			1	51	–	0.12	0.48	0.13
			1	51	–	0.03	0.29	0.13
			1	51	–	0.55	0.55	0.02
Lindane	F	1967	1	72	–	n. d.	0.38	0.11

n. d.: not detected. *Ikke påvist.*

–: no analysis made. *Ikke analyseret.*

sprayed and unsprayed plots are not significant.

Ficedula hypoleuca. On the large forest plots the general trend after both spraying years is a rise in population. In the other years there were far greater mutual differences in population trends than for tit species. In the small plots the number of broods did not exceed two per plot.

DISCUSSION

General remarks

The literature on the effects of insecticidal sprayings on bird life in forest is extensive. The background, however, usually differs strongly in respect of climate, forest type, tree age and height, season of spraying, and the bird species involved. The spraying methods differ in respect of insecticides, dosages and application tech-

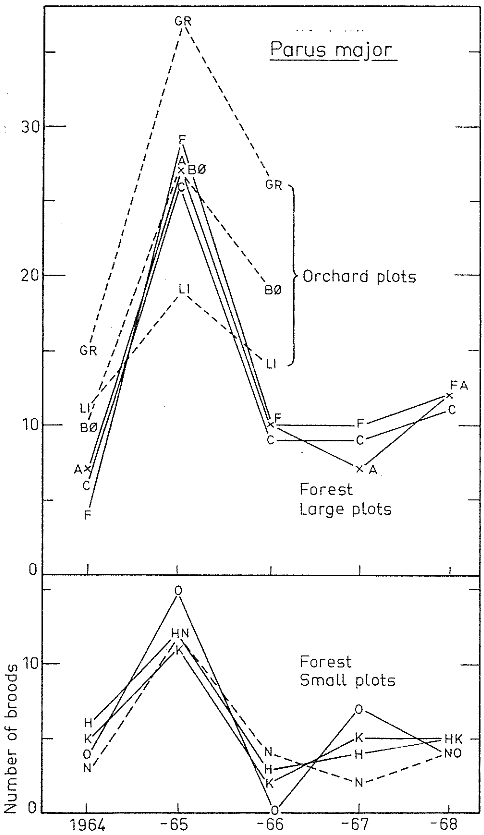

Fig. 1. *Parus major.* No. of first broods. A, C, F major and H, K, N, O smaller forest plots. GR, BØ, and LI: orchard plots.

Fig. 1. Musvit. Antal første kuld. A, C, F større og H, K, N, O mindre skovparceller. GR, BØ LI: frugtplantager.

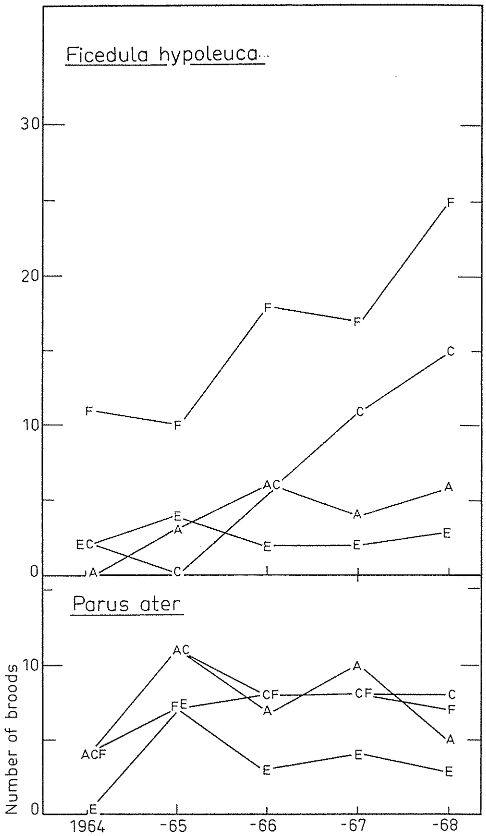

Fig. 2. *Ficedula hypoleuca* broods and *Parus ater* 1st broods. A, C and F are the major plots, E the sum of the small plots.

Fig. 2. Ficedula hypoleuca *kuld og* Parus ater *1. kuld. A, C og F er de større parceller, E summen af de små parceller.*

niques. Consequently comparisons are often of very limited value. Here only the very few publications found relevant are considered including some general works.

DDT

In the DDT plots it is conspicuous that disregarding a single *Parus ater* nestling (plot K, 1965, not analysed) losses occurred in *Parus major* only. Here a significantly higher nestling loss is found in one DDT plot in 1965 (K), and simultaneously more broods with high losses and a lower ratio fledgelings/eggs occurred than in the comparisons. The other DDT plot 1965 (H) shows the same trend of results, but far from significance levels. In 1967 no losses on the DDT plot were reported.

WURSTER et al. (1965) presumed DDT poisoning (insectivorous birds) when residues were above 30 ppm total DDT (DDE + DDD + DDT) by analyses of whole bodies. In Herring Gulls contaminated with DDT KEITH (1966) found that whole bodies of three youngs, died at an age of one week, contained 35-48 ppm DDT, 308-365 ppm DDE and 10-16 ppm DDD. DYCK et al. (1972) found that nestlings of *Parus major*, killed for analysis, contained 0.57-4.4 ppm DDE and 0.31-3.4 ppm DDT.

In the present investigations losses of *P. major* nestlings in the DDT treated plots (H 1965, K 1965 and N 1967) occurred in 6, 5 and nil broods resp.

Chemical analyses of nestlings from 2 broods from plot H 1965 indicated higher concentrations of DDT (0.60 and 2.8 ppm) than found in nestlings from the untreated plots C 1965 and O 1967 ($<$ 0.01 to 0.18 ppm). However, the concentrations of the metabolite DDE were at the same level as that found in nestlings from the unsprayed areas.

From plot K 1965 nestlings from 4 broods were analysed. The concentrations of DDT in nestlings from 2 of these broods were found to be higher (0.47 to 0.60 ppm) than in nestlings from the untreated areas, while the concentrations in nestlings from the other two broods were at the same level as that found in nestlings from the unsprayed areas. Nestlings from plot K were not analysed for DDE. The residues found cannot explain the significantly higher mortality of *P. major* nestlings from this area. Only one nestling of *P. ater* was lost on the DDT treated areas; this was not analysed. Analysis of *P. ater* nestlings from other plots from 1967 indicated concentrations from $<$ 0.01 to 0.33 ppm DDT and from 0.12 to 0.54 ppm DDE.

No broods of *Ficedula hypoleuca* lost nestlings in the DDT treated plots H and K 1965. In 1967 there were no flycatcher broods in the DDT treated plot. In dead nestlings from other plots from 1967 0.02-0.17 ppm DDT and 0.29-0.55 ppm DDE were found.

The general level of DDT in nestlings in Grib Forest

It is not possible to make a direct comparison between the DDT level in Grib Forest and the level in nestlings from other forests as most authors have analysed organs of birds, generally liver, brain and muscles.

DYCK et al. (1972) have analysed 64 nestling samples and 6 adults from Danish orchards sprayed with various pesticides including DDT. They found 0.18-26 ppm DDE and $<$ 0.01 to 3.7 ppm DDT in whole bodies of dead and killed individuals. WURSTER et al. (1965) have examined birds found dead after spraying of an area of 271 ha with 2.1 kg DDT per ha. Of the 99 birds, analysed in this work, 65 were found to contain above 30 ppm total DDT. In comparison with these concentrations those found by the authors of this paper are very low, possibly because of the small areas involved.

Comparison with other DDT-sprayings in forest

As mentioned above the analyses do not explain the rather conspicuous mortality of *P. major* nestlings found especially in one DDT plot. As a possible explanation starvation due to insecticidal reduction of food might be proposed. When compared with the other sprayed plots it is then further necessary to imply: a) a year with a very high bird population and hence a high degree of competition, b) a persistent insecticide and c) a very quick reduction in nestling loss when the size of the sprayed area is reduced to under 5 ha. It is, however, still difficult to explain that no corresponding mortality occurred in *Parus ater* which of necessity must feed inside the area sprayed.

A larger number of DDT sprayings in immense forest areas have been carried out in North America often with a dosage similar to that used in this experiment, but usually compounded on an oil basis instead of on water. This should mean a greater risk. Several observations on bird populations and nestling mortality are usually summarized as follows: single applications of dosages of about 1 kg DDT in oil/ha have no effect on bird numbers and breeding success. At 3 kg DDT/ha there is a considerable mortality in nestlings but not in adults. Higher dosages or repeated treatments are hazardous (BROWN 1961). A recent investigation in Switzerland (SCHIFFERLI 1966) compares the effect of 1.25 kg DDT to 1 kg phosphamidon in water from a helicopter on 707 and 1048 ha larch forest. No population changes or mortality were found in the DDT area, and fledgelings were numerous. The phosphamidon plot showed a 70% reduction in adults, several dead adults were found and the mortality in nestlings was similarly evaluated to about 70%. In the following year the bird numbers were normal again.

It therefore seems that the small loss of *P. ater* and *F. hypoleuca* nestlings found by the authors in plots treated with 1.0 kg DDT per ha is in agreement with the above-mentioned literature.

In P. major the same low nestling loss was found in two of the three DDT plots. In the third plot (K) the higher nestling loss is not explained by the DDT and DDE residues. In this case possibly a reduction of food supply has been of importance.

Lindane

Lindane was applied in 1967 only. In both plots losses were negligible in all three bird species. It should perhaps be kept in mind that 1967 was a year with a lower tit density and mortality than 1965.

One brood of *P. major* suffered losses in each of the lindane treated plots (F and K 1967). These nestlings had disappeared from the nests. Chemical analysis was made on 2 nestlings from K, 1967, killed for analysis. Traces of lindane (less than 0.01 ppm) were found in one of them; lindane could not be detected in the other one. For the sake of comparison it should be mentioned that lindane could not be detected in nestlings from 5 different broods from the untreated areas C 1965 and O 1967, while one nestling from a DDT treated plot (H 1965) contained 0.07 ppm lindane.

Only one *P. ater* nestling was lost in first broods after lindane spraying; this nestling was not analysed. A number of nestlings from second broods killed for analysis contained < 0.01 to 0.15 ppm lindane. In 1967 0.01 ppm lindane was found in a single second brood nestling from the untreated plot C. Losses of *Ficedula* nestlings occurred in one of the lindane treated plots only. Only one nestling from these 4 broods with losses was analysed, and lindane could not be detected in this nestling. However, analyses of some nestlings from a brood from a malathion treated plot (A 1967) indicated concentrations of lindane between 0.02 and 0.55 ppm.

The general lindane residue level in the nestlings from Grib Forest

CRAMP and CONDER (1965) have found

concentrations of BHC from < 0.01 to 0.23 ppm in nestlings of various species. DYCK et al. (1972) found from < 0.01 to 0.06 ppm lindane in nestlings killed for analysis, and from < 0.01 to 1.3 ppm lindane in dead nestlings of *Paridae, Ficedula* and Tree Sparrows *(Passer montanus)*. WEIHE (not. publ.) found from < 0.01 to 0.11 ppm lindane in the lipoid phase of the adipose tissue of pheasants killed for analysis.

The lindane concentrations found in this investigation: from < 0.01 to 0.15 ppm in nestlings killed for analysis and from <0.10 to 0.55 ppm in dead nestlings are at about the same low levels as those found by the above-mentioned authors.

Comparison with other lindane sprayings in forest

Application of 400 g lindane/ha from helicopter against cockchafers (Melolontha) was carried out on 29 ha (11.5.1956) and was repeated (18.5) on 25 ha with 200 g dieldrin plus 200 g lindane (PRZYGODDA 1957). All nestlings and some adults inside the dieldrin zone as well as at a 50 meter distance outside were found dead within 10 days (more than 100 broods). Outside this area no losses occurred. The above author is inclined to ascribe nearly all mortality to dieldrin.

At Krengerup forest district (Funen, Denmark) control of the aphid *Dreyfusia nordmannianae* was conducted in a similar manner and using 400 g lindane per ha on 11 ha (24.4.1963). Nest boxes were set up in the area and, for comparison, in an unsprayed area on April 5th. The tits *(Paridae)* this year began egg-laying about May 1st. The result is given in Table 10. It should be noted, that the *Ficedula* brood died about 6 weeks after spraying. It is highly improbable that lindane could influence this late brood and not the *Paridae* which breed earlier. In all, therefore, the small evidence points to little or no mortality caused by lindane spraying of the areas, in respect of dosages and bird species involved here.

Application of BHC or of lindane as a powder is a method rather different from lindane spraying. No significant bird mortality is known to result from dosages normally used.

Parathion

Parathion was applied in 1965 and to one plot only.

The loss of *Parus major* nestlings in this plot was of the same order as the loss in the untreated plots in the same year.

The loss of *Parus ater* nestlings was signifi-

Table 10. Lindane spraying, Krengerup 1963.

Tabel 10. Lindan-sprøjtning, Krengerup 1963.

Treatment *(Behandling)*	Not sprayed *(usprøjtet)*		Sprayed *(sprøjtet)*	
Nest boxes No. *(Redeks. antal)*	28		30	
Genus *(Slægt)*	*Paridae*	*Ficedula*	*Paridae*	*Ficedula*
Broods No. *(Antal kuld)*	8	2	8	1
Eggs No. *(Antal æg)*	55	10	59	6
Not hatched *(Uklækket)*	4[1])	1	1	–
Fledgelings *(Unger fløjet)*	51	9	57	0
Nestlings dead *(Unger døde)*	0	0	1	6

[1]) *Parus cristatus*, 2nd brood disturbed by woodpecker *(Topmejse, 2. kuld forstyrret af spætte)*.

cantly higher in the parathion treated plot than the loss in the untreated plot.

The loss of *Ficedula* nestlings (36%) in this plot is difficult to evaluate because only one single brood was present in the untreated plots in 1965; in addition the loss of *Ficedula* nestlings ranged from zero to 36 % in non-spraying years.

PALUDAN (1953) mentions 1.5 g parathion/kg pheasant as fatal.

Analysis of one brood of *Parus major* showed 3.1 ppm p-nitrophenol calculated as parathion (8 nestlings) and the authors presume this to be compatible with the supposition that this brood died from parathion poisoning.

In one *Parus major* nestling traces of p-nitrophenol were found; these may possibly have contributed to its death. In another nestling no p-nitrophenol was detected. These two nestlings were both from broods with only one nestling lost in each.

In three broods of *Parus ater* great losses of nestlings occurred. The analysis (4.9 and 11 ppm p-nitrophenol calculated as parathion) shows concentrations so high that it must be presumed that the nestlings died from parathion poisoning. Similar to the results for *P. major* only traces of p-nitrophenol were found in one nestling from a brood in which only this particular nestling died.

The *Ficedula* nestlings from the single brood with losses died about four weeks after spraying; p-nitrophenol was not detected in them.

Comparison with other parathion sprayings

In this experiment parathion caused some confirmed losses of nestlings mainly among *Parus ater*. Parathion is rarely used for forest spraying and very few, if any, field experiments or well founded observations have been made. The feeding experiments of PRZYGODDA (1957) clearly demonstrate that a great risk is involved for young tit nestlings. Thus the timing of this experimental spraying has probably influenced the results.

In Columbia parathion (concentration not known) has inflicted slight losses on doves, quail, and pheasants and often killed any songbirds remaining in the area during application (RUDD and GENELLY 1956, from BROWN 1961). The death of at least 27,000 birds in 1960 in the Netherlands is ascribed to the use of parathion for illegal seed treatment intended to kill pidgeons (BRUIJNS 1963). On the other hand pheasant chicks did not seem to be harmed by the spraying dosage used in Denmark (PALUDAN 1953, DALGAARD-MIKKELSEN and FOG 1968), nor was any obvious damage to bird life reported from some Danish sprayings of forest (DAHL and BEIER PETERSEN 1960).

Malathion

In the malathion treated plots *P. major* seemingly suffered smaller losses than in the untreated plots.

The loss of *P. ater* nestlings seems to be higher in one malathion treated plot than in the untreated plots in 1965, but the difference is not significant. In two malathion treated plots in 1967 the losses of nestlings are 0 and 2%.

The losses of *Ficedula* nestlings (28% and 22 %) are difficult to evaluate for the same reason as described on p. 38.

PRZYGODDA (1960) fed larvae dipped in a solution containing 0.2% malathion to 5-10 days old nestlings of *Parus major*. Daily weighings of the nestlings over 3 weeks did not reveal growth differences between these nestlings and controls.

Measurement of the cholinesterase activity in brain-tissue from two dead *P. major* nestlings coming from a plot sprayed with malathion showed enzymatic activity (1413 µl CO_2 per 100 mg brain-tissue per 30 min.) at the same level to that found in brain-tissue from chickens, which had not been in contact with cholinesterase inhibiting substances.

Brains from only one brood (eight nestlings) of five *P. ater* broods with losses were examined and showed a reduced enzymatic activity (320 μl CO_2 per 100 mg brain per 30 min.). This suggests that the brood in question suffered from poisoning with substances inhibiting cholinesterase, e. g. malathion.

Analyses of brains from two of the three *Ficedula* broods with losses (6 and 7 nestlings) revealed a reduced cholinesterase activity (322 and 723 μl CO_2 per 100 mg brain per 30 min.) suggesting that malathion may have contributed to the death of these nestlings.

Comparison with other malathion sprayings

Similar to the parathion cases the authors found some confirmed losses due to malathion. This is to some extent a surprising result as malathion, in the dosages applied here, is generally considered to be far less hazardous to birds. Losses caused by malathion are rarely, if ever, reported and discussed, even though malathion is sprayed on enormous areas of orchards and forests each year (Brown 1961). The excellent review by Mellanby (1967) declares it to be one of the safest insecticides in use.

General evaluation of the effect of spraying for all three species

The maximal reduction found in the sprayed plots (39%) is well below the theoretical natural mortality per annum. This is about 83%, 82% and 75%, in *P. major, P. ater* and *Ficedula,* assuming 10, 9 and 6 eggs, respectively, and an unchanged breeding population from one year to another. Reduced competition for food would normally compensate for the loss inflicted, as Lack (1966, p. 79) ascribes the main juvenile mortality to food shortage. According to the analyses the residues of insecticides in the survivors are low.

The reduction in population from 1965 to 1966, especially in the tits (Figs. 1, 2) is much greater than can be accounted for by the sprayings. The breeding population of 1966 constitutes only about 7% of the surviving tits (about 1065) of 1965, and about 30% of the breeding population of 1965 (all plots). Some other factors must have caused the reduction. The similar trend for orchards and the parallel reduction in the differently treated orchards both point to some factor associated with climate (e. g. availability of food in the colder winter of 1965/66). Similar "natural" reductions after peak years are known from England (Lack 1966). As mentioned under the discussion of DDT much higher losses than found by the authors were completely replaced the following year, and it is a general observation that sprayings of the type discussed here do not imply population reductions lasting longer than the spraying year. The results from 1967-68 further support this.

Residue levels in Grib Forest

In 1965 (before spraying was carried out) the concentrations of DDT and DDE in eggs (Table 3) were 0.02-0.72 ppm DDT and 0.38-0.58 ppm DDE. Lindane was not detected in these eggs. For 1967 the corresponding figures were 0.01-0.15 ppm DDT, 0.67-2.9 ppm DDE, and $<$0.01 to 0.07 ppm lindane. The slight rise of DDT + DDE from 1965 to 1967 may have been caused by the experimental sprayings, but lindane was not applied before egglaying in 1967 and may originate from localities outside the forest; this may also be the case for DDT and DDE.

The levels found in eggs are a little higher than some English analyses of eggs from Blue Tit: 0.07-0.46 ppm DDE plus 0.03 ppm BHC (CRAMP and CONDER 1965) and 0.15-0.18 ppm DDD plus 0.42-0.53 ppm DDE plus < 0.01 to 0.03 ppm BHC (CRAMP and OLNEY 1967). DDT was not detected in either case. On the other hand the levels are considerably lower than in eggs from Danish orchards: 0.32-102 ppm total DDT plus < 0.01 to 0.5 ppm lindane (DYCK et al. 1972). The general residue level in eggs in Grib Forest did not influence their hatching, as hatching and breeding success were generally high.

In the forest DDT and metabolites will be found in the soil for several years and lindane for some years (e. g. NASH and WOOLSON 1967). After the spraying in Grib Forest the bird population will therefore be expected to take up a little chlorinated insecticide in their food for a number of years even if they restrict their foraging range to forest. Even under such conditions the residue level seems to fall rather strongly in a year as shown in *Parus ater* by WALKER (1966). One week after a DDT spraying, similar to that used in Grib Forest, he found a level of DDT plus metabolites of about 19.3 ppm in breast muscle and 51.4 ppm in liver. Thirteen months after spraying only about 7% of this remained.

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SUMMARY AND CONCLUSIONS

This study concerns the effect on forest birds breeding in nest boxes following insecticidal sprayings from helicopter. Sprayings were carried out in 1965 and 1967 in two plots of about 20 ha and in three plots of about 3-6 ha, while one plot of each size and all plots in 1964, 1966 and 1968 served for comparison. The insecticides used were DDT (1000 g/ha), lindane (320 g/ha), parathion (350 g/ha) and malathion (900 g/ha). About 500 nest boxes were involved. They were mainly inhabited by Great tit *(Parus major)*, Coal tit *(P. ater)* and Pied Flycatcher *(Ficedula hypoleuca)*.

The sprayings were carried out at a season when very young tit nestlings were most numerous (flycatcher breeding was later) in order to measure the highest effect possible on the birds.

For Pied Flycatcher the results were difficult to evaluate, especially those from 1965, because only a single brood was

found on the untreated plots that year. In addition, the loss of nestlings in the untreated plots ranged from zero to 33% during the investigations.

The main findings were:

1. *Control areas*

a. The breeding success in all plots in the year before the first spraying and on the untreated plots in the following years ranged from 87-100% *(Parus major)*, 88-100% *(Parus ater)* and 64-100% *(Ficedula hypoleuca)*.

b. The loss of nestlings ranged from 0-12%, 0-10% and 0-33% resp. in *Parus major*, *Parus ater* and *Ficedula hypoleuca.*

2. *Parathion spraying*

a. The breeding success of *Parus major* (84%) and *Parus ater* (65%) did not deviate significantly from that found in the untreated plots. The breeding success of *Ficedula hypoleuca* was 50%.

b. The loss of *Parus major* nestlings (9%) was of the same order as found in the untreated areas, but the loss of *Parus ater* nestlings (31%) was significantly higher in the treated plot. The loss of *Ficedula hypoleuca* nestlings was 36%.

c. The insecticide residue found (p-nitrophenol calculated as parathion) ranged from 'not detected' to 3.1 ppm in *Parus major* nestlings (from 3 broods) and from 'trace' to 11 ppm in *Parus ater* nestlings (from 4 broods). In nestlings from one brood of *Ficedula hypoleuca* p-nitrophenol could not be detected.

3. *Malathion sprayings*

a. The breeding success in the malathion treated plots *(P. major:* 88%, 89%, 98% and 100%; *P. ater:* 59%, 90% and 100%; *Ficedula hypoleuca:* 72%, 78% and 100%) did not deviate significantly from that found on the untreated plots.

b. The loss of nestlings *(P. major:* 0%, 0%, 4% and 8%; *P. ater:* 0%, 2% and 26%; *Ficedula hypoleuca:* 0%, 22% and 28%) did not deviate significantly from that in the untreated plots.

c. The cholinesteraseactivity in the brain tissue indicated normal enzyme activity in one *P. major* brood, but reduced enzyme activity in one *P. ater* brood and 2 *Ficedula hypoleuca* broods.

4. *DDT sprayings*

a. The breeding success af *P. major* (49%, 84%, and 100%) deviated significantly from that found on the untreated plots in one of the DDT treated plots, but not in the other 2 plots. The breeding success of *P. ater* was 97% and of *Ficedula hypoleuca* (two plots) 100%.

b. The loss of *P. major* nestlings (0%, 10%, 43%) differed significantly from the results on the untreated areas in one DDT treated plot, but not in the two other plots. The loss of *P. ater* nestlings was 3% and of *Ficedula hypoleuca* (two plots) 0%.

c. The residues in dead nestlings from the DDT plots ranged from 0.10 to 2.8 ppm DDT and from 0.22 to 0.37 ppm DDE (from resp. 6 and 2 *P. major* broods).

5. *Lindane sprayings*

a. The breeding success on the lindane treated plots *(P. major:* 93% and 95%; *P. ater:* 96% and *Ficedula hypoleuca:* 94% and 100%) did not deviate significantly from the results from the untreated plots.

b. The loss of nestlings on these areas *(P. major:* 1% and 5%; *P. ater:* 2% and *Ficedula hypoleuca:* 0% and 4%) did not deviate significantly from losses in the untreated areas.

c. Residues of lindane could not be detected ($<$ 0.01 ppm) in dead nestlings (from 2 broods) from these areas.

6. Losses in tits were generally higher in both treated and untreated plots in the year with a peak population (1965).

7. It is concluded that insecticidal sprayings on plots of sizes like those described here have no influence on the bird population in the following years.

DANSK RESUMÉ

Om virkningen af kemisk insektbekæmpelse i skov på fugle ynglende i redekasser.

For at belyse virkningen på fugle af insecticidsprøjtning ophængtes i Grib Skov 1964 ca. 500 redekasser i 7 nåletræarealer. Helikoptersprøjtning udførtes i 1965 og 1967 tidligt i juni, når der var maximalt antal af nyklækkede mejseunger, for at fremkalde størst muligt udslag.

I 1965 anvendtes DDT, parathion og malathion, i 1967 DDT, lindan og malathion. Detaljer vedrørende sprøjtninger, arealer m. v. fremgår af tabel 1. Antallet af kuld af de tre vigtigste fuglearter, nemlig Musvit *(Parus major)*, Sortmejse *(P. ater)* og Broget Fluesnapper *(Ficedula hypoleuca)* ses i tabel 2. De øvrige arter (nævnt p. 33) var for fåtallige til at indgå i sammenligninger; men iøvrigt kunne ingen giftpåvirkning af dem umiddelbart fastslås. I 1965 og 1967 var ægantallet på parcellerne: Musvit 7,5-8,5 og 8,5-10,5, Sortmejse 6,7-8,5 og 8,2-10,0 og for Fluesnapperen henholdsvis 4,5-6,6 og 6,0-7,0. Redekasserne blev tilset flere gange i ynglesæsonen, og i sprøjtningsårene særlig ofte kort efter sprøjtningen. Døde unger og efter- eller forladte æg indsamledes til analyse for insecticidrester.

Ynglesucces (udfløjne unger som procent af antal lagte æg) og ungetab (unger døde eller forsvundne senere end sidste inspektion før sprøjtningerne) er angivet artsvis i tabellerne 4, 6 og 8.

På grund af det lave antal kuld på flere af parcellerne er de statistiske beregninger oftest foretaget med unger og æg som enhed.

Yngleresultaterne for Fluesnapperen er vanskelige at vurdere særligt i 1965, hvor der kun fandtes et enkelt kuld på kontrolarealerne. Desuden varierede ungetabet mellem 0 og 33% på kontrolparcellerne i undersøgelsesårene.

Som analysemateriale er anvendt æggeblomme + æggehvide og for ungernes vedkommende flået hoved + krop. Hvor der refereres til mere end et individ, er analyserne foretaget på det samlede materiale. Resultaterne fremgår af tabellerne 5, 7 og 9.

De vigtigste resultater er følgende:

Kontrolparceller

a. Ynglesuccesen på samtlige parceller året før sprøjtningerne blev foretaget, samt på ubehandlede parceller i de følgende år, varierede mellem 87-100% (Musvit), 88-100% (Sortmejse) og 64-100% (Fluesnapper).

b. Ungetabet på disse parceller lå mellem 0-12%, 0-10% og 0-33% for henholdsvis Musvit, Sortmejse og Fluesnapper.

Parathion-behandlede parceller

a. Ynglesuccesen hos Musvit (84%) og Sortmejse (65%) var ikke significant lavere end på kontrolparcellerne.

For Fluesnapperens vedkommende var den 50%.

b. Ungetabet hos Musvitten (9%) var her af samme størrelse som på de ubehandlede parceller, mens Sortmejsens ungetab (31%) var significant større på denne parcel. Tabet af Fluesnapperunger var 36%.

c. Insecticidkoncentrationer (p-nitrofenol beregnet som parathion) varierede mellem ikke påviselige mængder og 3,1 ppm i Musvitunger (fra 3 kuld) og mellem spor og 11 ppm i Sortmejseunger (fra 4 kuld). I Fluesnapperunger fra 1 kuld kunne p-nitrofenol ikke påvises. Vi formoder, at parathion i hvert fald har været medvirkende årsag til ungernes død i de tilfælde, p-nitrofenol er påvist.

Malathion-behandlede parceller

a. Ynglesuccesen på de malathion-behandlede parceller (Musvit: 88%, 89%, 98% og 100%; Sortmejse: 59%, 90% og 100%; Fluesnapper: 72%, 78% og 100%) var ikke significant lavere end de tilsvarende tal fra kontrolparcellerne.

b. Ungetabet på disse parceller (Musvit: 0%, 0%, 4% og 8%; Sortmejse: 0%, 2% og 26%; Fluesnapper: 0%, 22% og 28%) var ikke significant højere end de tilsvarende ungetab på kontrolparcellerne.

c. Cholinesteraseaktivitetsbestemmelse i hjernevæv tydede på normal enzymaktivitet i et Musvitkuld, mens der i et Sortmejsekuld og to Fluesnapperkuld fandtes reduceret cholinesteraseaktivitet. Vi formoder, at den reducerede enzymaktivitet har været medvirkende årsag til ungernes død.

DDT-behandlede parceller

a. Ynglesuccesen hos Musvit (49%, 84% og 100%) fandtes significant lavere på én af de DDT behandlede parceller end på kontrolarealerne; på de to andre var den ikke afvigende fra kontrolparcellerne. Sortmejsens ynglesucces var 97% og Fluesnapperens (to parceller) 100%.

b. Ungetabet hos Musvitten (0%, 10% og 43%) var significant større på ét af DDT arealerne.

mens det på de to andre DDT parceller lå inden for ungetabets variationsbredde for kontrolparcellerne. Sortmejsernes ungetab var 3% og Fluesnapperens (to parceller) 0%.

c. Koncentrationen af DDT og DDE i døde unger fra disse parceller lå mellem 0,10-2,8 ppm DDT og 0,22-0,37 ppm DDE (henholdsvis 6 og 2 kuld af Musvitter).

De påviste koncentrationer af DDT og DDE har næppe haft nogen indflydelse på ungernes død.

Lindan-behandlede parceller

a. Ynglesuccesen på de med lindan behandlede parceller(Musvit: 93% og 95%; Sortmejse: 96% og Fluesnapper: 94% og 100%) var ikke significant lavere end på kontrolparcellerne.

b. Ungetabet på disse parceller (Musvit: 1% og 5%; Sortmejse: 2% og Fluesnapper 0% og 4%) var ikke højere end tilsvarende tab på kontrolparcellerne.

c. Lindan kunne ikke påvises (< 0.01 ppm) i døde unger (fra 2 kuld) fra disse parceller.

Ungetabet hos mejserne var størst både på sprøjtede arealer og kontrolparceller i året med størst mejsepopulation (1965).

På arealer af størrelse som de i denne undersøgelse involverede, synes de her benyttede typer sprøjtninger at være uden væsentlig betydning for fuglebestandens størrelse de følgende år.

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