POPULATION TREND, REPRODUCTION, AND PESTICIDES IN DUTCH SPARROWHAWKS FOLLOWING THE BAN ON DDT

P. OPDAM, J. BURGERS & G. MÜSKENS

Research Institute for Nature Management, P.O. Box 46, 3956 ZR Leersum, The Netherlands

Received 18 March 1985, revised 1 July 1986

CONTENTS

1. INTRODUCTION

In the 1960s, Dutch Sparrowhawk *Accipiter nisus* populations suffered from the adverse side-effects of organochlorine pesticides. Mass mortality of birds of prey, including Sparrowhawks, occurred almost yearly as a result of the application of these compounds for seed dressing (Fuchs 1967, Koeman *et al.* 1969, 1971, Opdam 1985). In the same time, the population density decreased rapidly throughout the country (Koeman *et al.* 1972). The same trend was observed in adjacent areas (for GFR see Thielcke 1975). The population crash might well have been caused by an increased annual mortality. Unfortunately, mortality changes were never estimated for this period. A second possible cause for the population decline was a reduction of the reproductive output. Koeman *et al.* (1972) found indeed a serious reduction in breeding success, which they attributed to DDE contamination. This compound causes death of embryos and thinning of eggshells resulting in frequent egg breakage (see also Newton & Bogan 1974). The drop in the mean number of fledged young per clutch in that period was estimated at 50–60% (Newton 1974, Opdam 1985).

Following the bans on most organochlorines in 1968–69, Dutch raptor populations recovered rapidly (Thissen *et al.* 1981, Van Dijk & Van Os 1982, Opdam 1985). For the Sparrowhawk, however, this was not so clear as in other species. Although dieldrin and HCB residue levels in Sparrowhawks dropped within a few years after the bans on their usage, DDE remained at approximately the same level of contamination (Fuchs *et al.* 1972). All applications of DDT in The Netherlands were prohibited from 1973 onwards.

The recovery of the Dutch Sparrowhawk became apparent in the mid-1970s, although DDE residues kept largely at the same level from 1975 up to 1983 (Burgers *et al.* 1986). This is not in agreement with the supposed role of DDE suppressing the reproductive output to such an extent that recovery was prevented (Koeman *et al.* 1972).

In the present paper, we re-examine the trend in the numbers of Dutch Sparrowhawks between 1970 and 1983, and look for changes in reproductive output which could be responsible for the reported population recovery. Also we assess the present impact of DDE on reproduction.

2. METHODS

2.1. STUDY AREAS

After an explorative year, in 1970 systematic data collection began in two adjacent areas (Nijmegen and Reichswald), situated between the towns of Nijmegen and Kleve. The two areas are separated by the Dutch-German frontier. Food studies were stopped after four years (Opdam 1975, 1978). However, the sampling of population parameters are still being continued.

Both areas are made up of an extensive forest enclosed by farmland with scattered woodlots, orchards, and villages. In 1977 a third locality lying between Rhenen and Doorn in the central part of The Netherlands was added to the other areas. This area resembles the other two in being a forested moraine surrounded by farmland. The next year, the Achterhoek area, which is a mosaic of small and medium-sized woods and fields with small villages and scattered farm houses, was included. Since 1981, the year in which the study was incorporated into the program of the Research Institute for Nature Management, we also received data from an area in eastern Brabant through the kind cooperation of J. van Diermen. This region resembles the Achterhoek area.

The numbers of nests located each year in the study areas are given in Table 1.

2.2. POPULATION TREND AND BREEDING SUCCESS

The best population estimate would be the number of pairs in the pre-nesting period. Being secretive and silent even in the mating season, Sparrowhawk pairs are difficult to locate. Their presence in nesting areas is indicated by droppings, prey remains, shed feathers, and newly-built nests. Most occupied nesting territories were located early in the incubation period. If nests were found till near the end of the season, it is possible that the sample was biased in favour of successful nests, which survive longest. As a population estimate we used the number of nesting areas with at least one egg laid.

Although the proportion of non-breeders is not precisely known, we consider the number of occupied nests as a reliable population estimate. To calculate a common population trend we used the data from the five populations investigated plus unpublished data kindly provided to us by R. G. Bijlsma (1973–82, SW-Veluwe) and H. Baayen (1972–81, NE-Veluwe). It was not possible to use the arithmetic mean, because the census data were from different, partly overlapping periods. Moreover, the size of the study areas was not equal. So for each interval of two successive years, a common trend was calculated for any of the populations. A curve was fitted in such a way, that for all regions the number of observed breeding pairs resemble that curve up to a certain constant which is specific for that area. This curve was fitted by means of multiple regression analysis (Genstat), which resulted in a loglinear model of a population index with year and area as explaining variables.

Breeding success was measured as the proportion of clutches which produced fledged young and as the mean number of fledglings in successful nests. Trends in breeding success were investigated on the basis of data from all breeding attempts recorded.

2.3. FACTORS GOVERNING BREEDING SUCCESS

Our primary interest was the effect of DDE on breeding output, but this effect could only be properly assessed in relation to other factors affecting the reproductive rate. The following factors were considered.

Egg/nestling predation. Mainly by Goshawk *Accipiter gentilis* and human intervention, including the removal of eggs for chemical analysis. We assumed that eggs removed early in the incubation period had an average chance to produce a fledged Sparrowhawk.

Age of breeding bird. Newton *et al.* (1979) found a better breeding performance for adult females than in yearlings. The latter are distinguished from adults using moulted feathers found at the nesting areas.

Food supply and feeding habitat. In Sparrowhawks, food supply affects the date of egg laying, clutch size, frequency of nest desertion, and mortality of chicks (Newton 1976). Because of lack of data on prey abundance, we applied an indirect measure, based on the amount of particular feeding habitats within a given distance from the nest. The majority of Sparrowhawk prey is captured in the woods, near houses, and in villages. Therefore, for each nest we estimated the following parameters from maps (1:25,000): the area of woodland within a 500 m radius (estimated as a percentage coverage), the number of houses within a 500 m radius, and the distance to the nearest village (in m). These measurements give only a rough estimate of the variation in food supply. For example, variations in forest and urban habitat types, are not accounted for by this method.

Residue levels of organochlorine compounds. Usually within one or two days after laying, one fresh egg was taken from several clutches (for the number of eggs sampled in each year and area, see Burgers *et al.* 1986). Eggs were frozen as soon as possible after sampling and analysed within a few months. Sample preparation, clean-up and gaschromatographical determination of organochlorine compounds are described in Burgers *et al.* (1986). Residue levels were expressed in ppm wet weight.

Shell thickness. Thin-shelled eggs are likely to break during incubation. Therefore, we measured shell thickness of sampled eggs as a factor affecting breeding success, using the Ratcliffe index (Ratcliffe 1970).

Clutch size. Obviously, clutch size is related to brood size, but not to whether the nest succeeds or fails. Clutch size was determined in nests from which an egg was sampled for analysis.

Some of these factors may be related. For example, high residue levels of DDE are usually found in thin-shelled eggs and, as a rule, yearling females lay smaller clutches than adults (Newton *et al.* 1979). We estimated the relative effect of each of these factors by stepwise multiple regression (Genstat package). For these calculations, we only used data from nests from which we collected eggs for analysis of organochlorine compounds.

3. RESULTS

3.1. POPULATION TREND

All populations increased during the periods they were studied (Table 1). The common trend, as shown by the weighted average of all seven populations, is depicted in Fig. 1. This figure shows an increase from 1970 onwards, through a slight regression, up to the 1976 level. After a short relapse the increase continued, but more slowly than before. If we accept the seven local populations as representative for the Dutch population as a whole, we may conclude that the Sparrowhawk did not differ from other raptor species which had suffered during the pesticide episode. Like the Buzzard *Buteo buteo* and Goshawk, this species started to recover in the early 1970s following the bans on most organochlorines, but before the final ban on all applications of DDT in 1973.

Table 1. Number of occupied nests found in each of the study areas.

Area	1969	70	71	72	73	74	75	76	77	78	79	80	81	82	83	Total
Reichswald	2	6	6	7	10	10	13	16	19	18	12	14	18	15	19	185
Nijmegen	2	7	8	13	9	7	13	11	16	16	16	20	26	29	26	219
Brabant							1	2	3	4	6	5	18	27	60	126
Utrecht									13	15	19	24	20	24	32	147
Achterhoek										19	33	28	32	41	46	199
Total	4	13	14	20	19	17	27	29	51	72	86	91	114	136	183	876

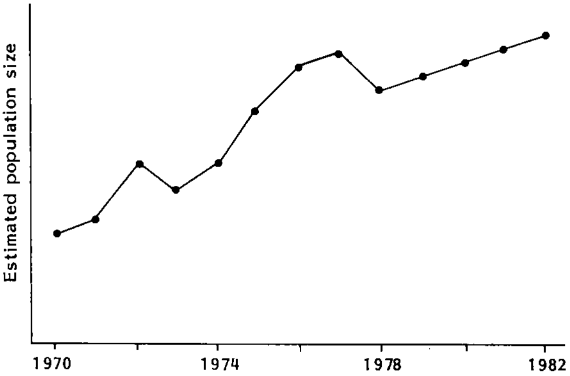

Fig. 1. Common trend in Dutch Sparrowhawks as derived from data in seven areas.

3.2. CHANGES IN REPRODUCTION

From 1970 to 1976 the proportion of successful breeding attempts fluctuated between 60 and 70%, with an outlying value in 1971, which is based on a small sample of 8 broods (Fig. 2). From 1977 onwards, all values are within the 70–80% range, with that for 1981 as an exception (83%). A comparison with Fig. 1 shows that the onset of the population increase preceded the recovery of breeding success. The following question to be dealt with concerns the role of DDE in this recovery. To estimate properly the impact of this compound on breeding output, the effects of other factors should also be known. In the following section the possible effects of predation and disturbance, age, feeding habitat, shell thickness, and DDE and other organochlorines are investigated separately.

3.3. FACTORS GOVERNING BREEDING PERFORMANCE

Predation and disturbance. In 244 (28%) of 876 nests no young fledged. In 119 nests, the clutch was deserted without any identifiable cause. In most cases, clutch desertion is attributable to poor condition of the female (Newton & Marquiss 1981). Of the remaining nests, 28 failed as a result of Goshawk predation, 37 as a result of intervention by man, 57 as a result of eggshell breakage, and 3 were destroyed by other natural forces.

Age of male and female. We distinguished the following categories of breeding pairs: those with both male and female in immature plumage, mixed pairs with either the male or female in immature plumage, and adult pairs. These categories differ markedly in brood size and breeding success (Table 2). Yearling pairs perform least well, adult pairs are most successful, while mixed pairs with yearling males tend to perform somewhat less well than mixed pairs with adult males. The same trend occurred in British birds (Newton *et al.* 1979).

The effect of male age is explained by assuming divergence in hunting abilities between experienced adults and less experienced yearlings. The role of food brought to the female to increase her body weight, and its significance in reproduction, was shown by Newton & Marquiss (1981). An explanation for the effect of female age may lie in the care of eggs and chicks, which may be less effective in immatures. The

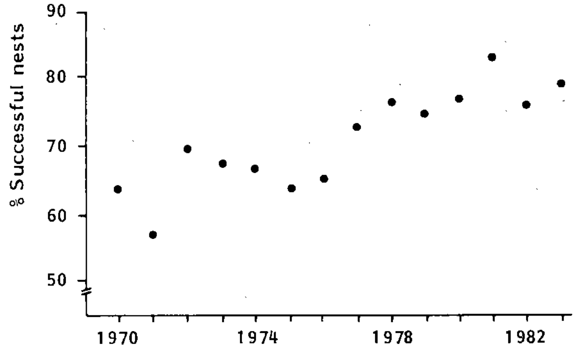

Fig. 2. Proportion of successful Sparrowhawk nests. Breeding failures include those caused by Goshawk predation and human intervention.

Table 2. Breeding performance and age.

Age		Number of nests	% successful	Mean number of fledglings per successful nest
Male	Female			
Imm	Imm	74	65	3.1
Imm	Ad	48	79	3.2
Ad	Imm	42	81	3.5
Ad	Ad	264	84	3.7

Table 3. Breeding success in relation to habitat. Mean brood size was calculated over all breeding attempts for nests with varying amounts of wood within 0.5 km radius (a) and for nests at various distances from villages (b).

a) % Wood	Number of nests	Mean brood-size	b) Distance to village (km)	Number of nests	Mean brood size
0– 25	11	3.45	0–1	37	3.16
26– 50	36	3.05	1–2	65	2.46
51– 75	38	2.68	>2	29	2.72
76–100	46	2.30			

larger brood size of adults is partly the result of the larger size of their clutches (see also Newton *et al.* 1979).

Feeding habitat. The number of fledglings per clutch decreased with the area of woodland surrounding the nesting site (Table 3). Furthermore, those hawks breeding less than a kilometre from villages showed better breeding results than those further away. This is attributable to differences in the amount of possible food. Most woods are relatively young plantations with low foliage height diversity and spatial heterogeneity, supporting comparatively poor songbird populations. In villages and near farm houses, on the contrary, numerous songbirds offer favourable feeding conditions to the Sparrowhawks.

DDE and shell thickness. DDE contents and shell thickness were related to brood size (Table 4, Fig. 5). Shell indices were lowest, on average, in clutches without success, and highest in nests producing 'normal' broods (2–6 young). With respect to DDE levels, the difference between the two categories of breeding success is not significant. Eggs with a shell index below 1.16 more often failed to hatch than eggs with thicker shells ($P < 0.05$). It may be expected that yearling females have smaller DDE contents in their eggs than adults, because the latter have been exposed to DDE intake through food for a longer time. In our data this was not generally the case (Table 5). Newton *et al.* (1981) found an increase in eggs between the first and second years of life, followed by a somewhat smaller decrease, which they attributed to excretion of organochlorines through the eggs.

Other organochlorine compounds. The HCB, dieldrin and heptachlor epoxide contents of the eggs were so small that adverse effects on breeding are very unlikely. For example, dieldrin (in ppm wet weight) ranged between 0.01 and 3.0. PCB levels were considerably higher. However, the possible effects of DDE and PCB on breeding are difficult to separate because the residue levels are correlated ($r = 0.29$, $p < 0.005$). Newton & Bogan (1978) suggested, however, that in Sparrowhawks, PCBs have less influence on egg addling than DDE, and no influence at all on egg breakage and shell thickness.

3.4. EFFECT OF DDE ON REPRODUCTION

In the preceding section it was concluded that

Table 4. Number of fledglings in relation to mean DDE contamination (median) in the eggs and mean eggshell index (arithmetic mean).

Number of fledglings	n	DDE	Eggshell index
0	26	10.8	1.14
1	8	12.1	1.21
2	14	11.5	1.16
3	27	7.7	1.23
4	32	8.0	1.26
5	15	11.3	1.26
6	3	7.3	1.25
0–1	34	11.1	1.16
2–6	91	8.5	1.24
Difference		N.S.	$p = < 0.05$

Table 5. DDE residues in the eggs of yearling and adult Sparrowhawks.

Year	Yearling females		Adult females	
	n	mean	n	mean
1975	6	9.9	10	10.0
1977	4	7.7	16	7.4
1981	11	10.2	30	11.5
1982	7	12.7	14	8.6
1983	7	5.6	29	8.5
Total	35	8.1	99	9.8

the reproductive output varied according to male and female age, DDE contents and eggshell thickness, the type of feeding habitat, Goshawk predation and disturbance by man. Changes in any of these factors may have caused the increase in reproductive output (Fig. 2), or may have interfered with the presumed relation between DDE and breeding success.

A proper estimate of the effect of DDE is further prevented by the relations among these factors. Immature birds may settle more often in suboptimal habitats than adults, while DDE contents and shell thickness are correlated.

A simple method to correct for predation by Goshawk and disturbance by man is to assume that eggs or young robbed would have had an average chance to produce a fledged bird. The effect of age of breeding birds may be excluded by selecting adult pairs. These adaptations have been made in Figs. 3 and 4. A comparison with Fig. 2 shows a more abrupt change in breeding success, the first year of the recovery being 1977. On the contrary, the average brood size changed hardly, if at all.

To account for the combined effect of all factors, we used a multivariate technique. Stepwise multiple regression analyses were done on the difference between success and failure (standard error assumed to follow a binomial distribution) and on the variation in number of young fledged (Poisson distribution). The effects of predation, disturbance, and egg collecting were eliminated beforehand. The resulting regression models are summarized in Table 6. Regressions were made for the five sampling years together, and for 1975 and 1977, and for 1981–82–83.

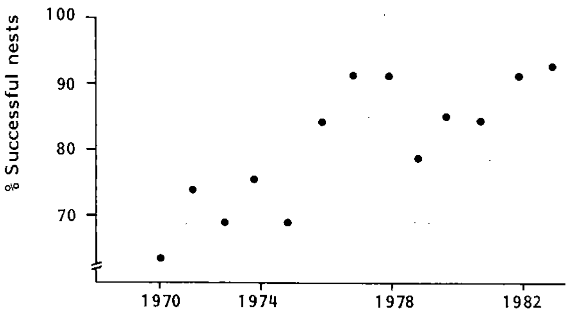

Fig. 3. Proportion of successful nests in adult breeding pairs (n = 273). Corrected for effects of human intervention and predation.

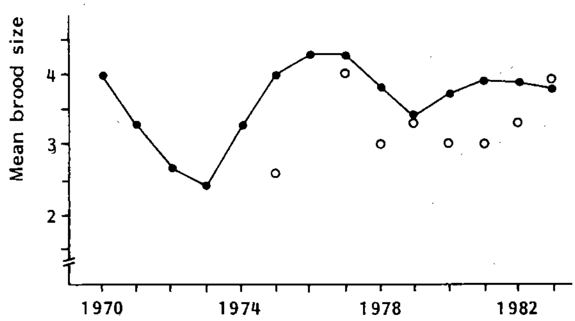

Fig. 4. Brood size in successful nests, separated for adult (dots) and yearling (open circles) females.

Table 6. Regression models for success and failure (a) and the number of fledglings (b).

a) binomial distribution	
1975–83	p = 1/1 + e (5.98–7.43 (index) + 0.023 (wood))
1975 and 1977	p = 1/1 + e (21.9–20.16 (index))
1981–83	p = 1/1 + e (−2.87 + 0.025 (wood))
b) Poisson distribution	
1975–83	log(number) = −1.59 + 2.101 (index)
1975 and 1977	log(number) = −2.86 + 3.148 (index)
1981–83	log(number) = −0.96 + 1.582 (index)

Variables for locality, year, female age, and organochlorine content were never selected. Amount of woodland in hunting range significantly correlated with breeding success and brood size in several subsets. However, eggshell thickness accounted for a significant part of the variation in almost all subsets. Its effect on breeding output was most severe in the first two years. Thus, variation in eggshell thickness shows a closer correlation with breeding performance than DDE does.

Variation in other factors does not account for a significant part of the variation in breeding success, or may be related to variation in shell thickness or habitat.

4. DISCUSSION

The Sparrowhawk populations under study, which can be assumed to have been at a low at the end of the 1960s, started to increase in the early 1970s, soon after most applications of persistent pesticides had been forbidden (Fig. 1). This recovery occurred despite the low breeding success at that time. From 1977 onwards, the rate of increase diminished considerably. This

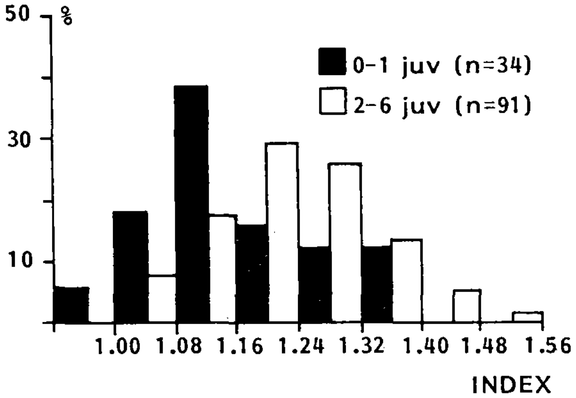

Fig. 5. Frequency distributions for nests with bad and good breeding results over eight categories of eggshell index.

change was followed by the reported recovery of reproductive output (Fig. 2). Therefore, in these populations, changes in breeding success could not have caused the increase in population size.

If the populations we studied were representative for the Dutch Sparrowhawk population as a whole, the recovery of the Dutch Sparrowhawk is not attributable to an increase in offspring production. Hence, it must have been caused by a decrease in adult mortality, presumably as a result of the disappearence, after the ban in the late 1960s, of HEOD and related compounds from the food chain in which the Sparrowhawk takes a top position (*cf.* Fuchs *et al.* 1972). It is also very likely that these compounds caused the decline in the 1960s, especially because mass mortality often took place in early spring, after normal winter losses had occurred.

For the Sparrowhawk on the British Isles, Newton & Haas (1984) came to the same conclusions. Smies (1983) simulated population trends in Sparrowhawks, using a model based on Newton's data and, for some parameters, on estimates derived from a Tawny Owl *Strix aluco* population. He found that Sparrowhawk populations in which the mean brood size decreases to 50% (which is the estimated decline in reproductive output during the pesticide era) can still maintain the same densities. Thus, the results of the computer modelling support our and Newton's conclusion, that the presumed role of DDE on the breeding success as a main factor suppressing Sparrowhawk populations is questionable.

Is the increase in breeding success from 1976 onwards attributable to a diminished DDE contamination? To answer this question, we have to compare data from the period before 1976 with data from later years (see Burgers *et al.* 1986 for details). DDE residues in 1975 were shown to be at the same level as in 1977 or later years, but the 1975 data were based on the assumption that the eggs in that year contained a fat content similar to the mean of eggs collected in later years. The increase in eggshell thickness (1.13 to 1.26) from 1975 to 1977 is significant, although later it diminished again slightly. It may also be of importance that the Ratcliffe index passed the value of 1.16, which was presumed to be critical for breeding success (Fig. 5). This could explain why the recovery in mean breeding success from 1976 onwards was so abrupt.

The best evidence for a decline of the DDE burden in Sparrowhawks was given by the decrease of more than 30% in the proportion of clutches with egg breakage between 1970 and 1976 (Burgers *et al.* 1986). Therefore, we suggest that breeding success improved due to an increase in eggshell thickness, which must have been caused by a diminishing DDE burden in Sparrowhawk females. We also suggest that before 1976 DDE only retarded the population recovery, if it had any effect.

Even after 1975, DDE caused eggshell thinning and affected the reproductive output of several pairs. DDE residue levels and eggshell thickness did not change during this period (Burgers *et al.* 1986). However, as suggested by the result in this paper, it is highly improbable that this adverse effect on reproduction would be of importance to the maintenance of population density.

5. ACKNOWLEDGEMENTS

Much of the fieldwork was done by M. van de Bout, J. van Diermen, E. van Manen, G. J. van Nie, N. van de Oosterkamp, R. Rook, J. Thissen, P. Verschuren and R. Zollinger. We are very grateful for their stimulating cooperation. J. Oude Voshaar gave invaluable advice and help on statistical problems. J. van Rhijn, A. Spaans and I. Newton critically commented upon the first draft and made very valuable suggestions for improvement.

6. SUMMARY

Dutch Sparrowhawk populations declined during the 1960s due to adverse effects of organochlorine pesticides. Almost immediately after the bans on the use of these compounds in agriculture, populations started to recover. The effect of DDE on reproduction was often assumed to be a major factor responsible for the decline.

We followed the reproductive output of several populations during the period 1970–83 to test the assumption that an improvement of the breeding performance was responsible for the recovery of the population.

Because breeding performance is governed by several factors other than organochlorines which, in their turn, may be connected with the amount of pesticides taken up by the birds, we also studied the effects of age of breeding birds, food supply as measured by landscape attributes in the feeding range, eggshell thickness and clutch size.

The proportion of successful clutches increased quite suddenly from 60–70% during 1970–75 to 70–80% from 1976 onwards, but Sparrowhawk populations had started to grow already before. We concluded that the recovery of reproduction had no effect on the breeding population, and suggest that the recovery of the Sparrowhawk was caused by a decrease in mortality due to disappearance of dieldrin and related compounds from the environment. The role of DDE in suppressing the Sparrowhawk populations is questioned.

Breeding performance was governed by both male and female age. Immature pairs performed least well, adult pairs were most successful, whereas mixed pairs were intermediate. Reproductive output decreased with the area of woodland surrounding the nesting site and with the distance to the nearest village. DDE content in eggs and shell thickness were related to brood size and general breeding performance. A threshold value for the effect of shell thickness is suggested. Multiple regression techniques were used to account for the combined effects of various factors on breeding performance. We concluded that eggshell thickness and amount of woodland in the hunting range were the best predictors of mean brood size and breeding success. It is likely that the increase in breeding success in the mid-1970s was possible after an increase of eggshell thickness.

7. REFERENCES

Burgers, J., P. Opdam, G. Müskens & E. de Ruiter. 1986. Residue levels of DDE in eggs of Dutch Sparrowhawks *Accipiter nisus* following the ban on DDT. Environ. Pollut. Ser B. 11: 29–40.

Dijk, A. J. van & B. L. J. van Os. 1982. Vogels van Drenthe. Van Gorcum, Assen.

Fuchs, P. 1967. Death of birds caused by application of seed dressings in The Netherlands. Med. Rijksf. Landb. Gent 32: 855–859.

Fuchs, P., J. Rooth & R. H. de Vos. 1972. Residue levels of persistent chemicals in birds of prey and owls in The Netherlands in the period from 1965–1971. TNO Nieuws 27: 532–541.

Koeman, J. H., C. F. van Beusekom & J. J. M. de Goeij. 1972. Eggshell and population changes in the Sparrowhawk (*Accipiter nisus*). TNO Nieuws 27: 542–550.

Koeman, J. H., J. Garssen-Hoekstra, E. Pels & J. J. M. de Goeij. 1971. Poisoning of birds of prey by methyl mercury compounds. Med. Rijksf. Landb. Gent 36: 43–49.

Koeman, J. H., J. A. J. Vink & J. J. M. de Goeij. 1969. Causes of mortality in birds of prey and owls in The Netherlands in the winter of 1968–1969. Ardea 57: 67–76.

Newton, I. 1974. Changes attributed to pesticides in the nesting success of the Sparrowhawk in Britain. J. appl. Ecol. 11: 95–101.

Newton, I. 1976. Breeding of Sparrowhawks (*Accipiter nisus*) in different environments. J. Anim. Ecol. 45: 831–849.

Newton, I. & J. Bogan. 1974. Organochlorine residues, eggshell thinning and hatching success in British Sparrowhawks. Nature, London 249: 582–583.

Newton, I. & J. Bogan. 1978. The role of different organochlorine compounds in the breeding of British Sparrowhawks. J. appl. Ecol. 15: 105–116.

Newton, I., J. Bogan & M. Marquiss. 1981. Organochlorine contamination and age in Sparrowhawks. Environ. Pollut. Ser. A: 25: 155–160.

Newton, I. & M. Marquiss. 1981. Effect of additional food on laying dates and clutch sizes of Sparrowhawks. Ornis Scand. 12: 224–229.

Newton, I., M. Marquiss & D. Moss. 1979. Habitat, female age, organochlorine compounds and breeding of European Sparrowhawks. J. appl. Ecol. 16: 777–793.

Newton, I., M. Marquiss & D. Moss. 1981. Age and breeding in Sparrowhawks. J. Anim. Ecol. 50: 839–853.

Newton, I. & B. Haas. 1984. The return of the Sparrowhawk. Brit. birds 77: 47–70.

Opdam, P. 1975. Inter- and intraspecific differentiation with respect to feeding ecology in two sympatric species of the genus *Accipiter*. Ardea 63: 30–54.

Opdam, P. 1978. Feeding ecology of a Sparrowhawk population (*Accipiter nisus*). Ardea 66: 137–155.

Opdam, P. 1985. Roofvogels in ons landschap. Spectrum, Utrecht.

Ratcliffe, D. A. 1970. Changes attributable to pesticides in egg-breakage frequency and eggshell thickness in some British birds. J. appl. Ecol. 7: 67–107.

Smies, M. 1983. Simulation of small bird populations. 2. Reduced breeding in two British raptor species. Ecol. Modell. 20: 279–296.

Thielcke, G. 1975. Das Schicksal der Greifvögel in der Bundesrepublik Deutschland. Kilda Verlag, Greven, BRD.

Thissen, J., G. Müskens & P. Opdam. 1981. Trends in the Dutch Goshawk *Accipiter gentilis* population and their causes. In: R. E. Kenward & I. M. Lindsay (eds.). Understanding the Goshawk. Int. Ass. Falc. Cons. Birds of Prey: 28-43.

8. SAMENVATTING

Ten gevolge van de nevenwerkingen van de in de landbouw toegepaste bestrijdingsmiddelen nam de Sperwer in Nederland in de loop van de jaren zestig in aantal af. Na verboden op het toepassen van de verdachte stoffen (o.a. DDT, dieldrin, kwikverbindingen) begonnen de nog resterende populaties zich te herstellen. Voor de Sperwer werd aangenomen dat de daling van de reproduktie als gevolg van DDE de belangrijkste factor was voor de achteruitgang.

Gedurende 1970–83 werden verscheidene populaties gevolgd met het doel na te gaan of een herstel van het niveau van de reproduktie zou optreden en of dit verantwoordelijk

kon worden geacht voor de toename van het aantal broedparen. Tevens zou de vraag moeten worden beantwoord of reproduktieherstel mogelijk was door een vermindering van de DDE-belasting.

Het bleek dat alle onderzochte populaties waren gegroeid, maar dat het tijdstip waarop de groei begon niet volgde op, maar voorafging aan het moment dat de reproduktie begon te verbeteren (Fig. 2). Daaruit moet worden geconcludeerd dat niet de reproduktiedaling, maar een mortaliteitsverhoging van volgroeide vogels de oorzaak moet zijn geweest van de achteruitgang van de Sperwer, en dat het herstel mogelijk werd na het verbod op zeer giftige, maar niet zeer persistente organochloorverbindingen als dieldrin en verwante stoffen.

Eerder was al vastgesteld dat de hoeveelheid DDE in sperwereieren tusen 1975 en 1983 niet noemenswaardig was teruggelopen (Burgers *et al.* 1986). Dit riep de vraag op naar de oorzaak van genoemde reproduktieverbetering. Een aantal factoren die mogelijk van invloed zouden kunnen zijn geweest werden onderzocht, te weten predatie en verstoring, leeftijd van broedvogels, landschappelijke kenmerken van het jachtgebied (als maat voor de hoeveelheid voedsel), andere organochloorverbindingen en het dunner worden van de eischaal. Al deze factoren vertoonden een verband met het niveau en de variatie in de reproduktie. Het schatten van het effect was echter moeilijk door de vele (mogelijke) interacties tussen de factoren. Na correcties voor de effecten van predatie door Havik, verstoring door de mens en het verzamelen van eieren voor onderzoekdoeleinden en voor de verschillen in broedsucces tussen onvolwassen en volwassen vogels bleek de toename in het broedsucces alleen maar duidelijker te zijn geworden (Fig. 3).

Deze verbetering is niet duidelijk terug te vinden in het aantal jongen dat gemiddeld uit succesvolle nesten uitvliegt. Door middel van multipele regressie werd vastgesteld dat de combinatie van het dunner worden van de eischaal en de structuur van het landschap in het jachtgebied (% bos, afstand tot dorpen) het beste correleerde met zowel de variatie in broedsucces als die in het aantal jongen.

Geconcludeerd kan worden dat een geringe toename in de eischaaldikte na 1975 de kans op eibreuk aanzienlijk heeft verminderd en dat daardoor het broedsucces is verbeterd. Niettemin speelt de invloed van DDE-vergiftiging nog steeds een rol in het broedsucces, maar deze is niet van invloed op de populatiedichtheid.