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Population Dynamics and Breeding Performance of the Goshawk *Accipiter gentilis* in Central Poland in 1982 - 1994

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ABSTRACT

The study was conducted in the Kampinoski National Park (360 km^2, 71% forest area), Central Poland, from 1982, six years after the Goshawk was given legal protection. Until 1994, 10-14 pairs per 100 km^2 were recorded yearly, one of the highest recorded densities for Europe. The population showed no long-term trend, and annual fluctuations in numbers were correlated with annual fluctuations in mean clutch size. Lower mean clutch size in years of lower population was due to increased proportions of 2-egg clutches. It is suggested that these were connected with 1-year females recruited to the breeding population after increased losses of adult birds. During 1989-94 breeding success declined from 2.5 to 1.7 fledglings per nest, owing mainly to an increase in complete nest failures not due to human persecution. However, these changes were not sufficient to affect the size of the Goshawk breeding population.

As compared with the period preceding legal protection of the species, the mean clutch size of the Goshawk in Kampinoski National Park increased by 1.1 eggs (40%), the mean proportion of 2-egg clutches decreased from 46% to 7.6%, the mean overall nest failures showed no significant change, and the number of young raised per breeding pair was doubled (1.2 and 2.9 respectively). Nevertheless the density in optimal nesting habitat was similar in both periods (25.0 and 26.5 breeding pairs per 100 km^2 wooded area).

INTRODUCTION

The large literature on Goshawk *Accipiter gentilis* numbers in Europe in the 19th and 20th centuries provides evidence for the occurrence of large

population fluctuations, including regional extinctions (e.g., in Britain). After the implementation of total or partial legal protection and the banning of DDT and other organochlorines in the 1970s, Goshawk numbers recovered in most areas. Based on over 100 surveys in 1950-1990 (after Cramp & Simmons 1980, Kalchrenter 1982, Link 1982, 1986, Marquiss & Newton 1982, Thissen *et al.* 1982, Fischer 1983, Saurola 1985, Buhler & Oggier 1987, Bijlsma 1989, 1991a, 1991b, Zang *et al.* 1989, Penteriani 1991, Sepiel 1992, Sulkava *et al.* 1994, and others), densities of Goshawks were found to vary from 1 to 8, occasionally up to 12-15 pairs per 100 km^2 of total area. Poland lies in the Great European Plain, where Goshawk densities seem to be higher than in many other parts of Europe. According to 17 surveys reviewed by Król (1985) and Drazny & Adamski (in press) the densities of Goshawks in Poland varied from 1.3 to 15.2 pairs per 100 km^2 of total area, and in 4 areas they reached over 10 pairs per 100 km^2.

The purpose of my study was to estimate the numbers and breeding performance of Goshawks in the Kampinoski National Park in Central Poland after complete legal protection of this species was introduced, and to compare them with similar data from the period before protection.

STUDY AREA

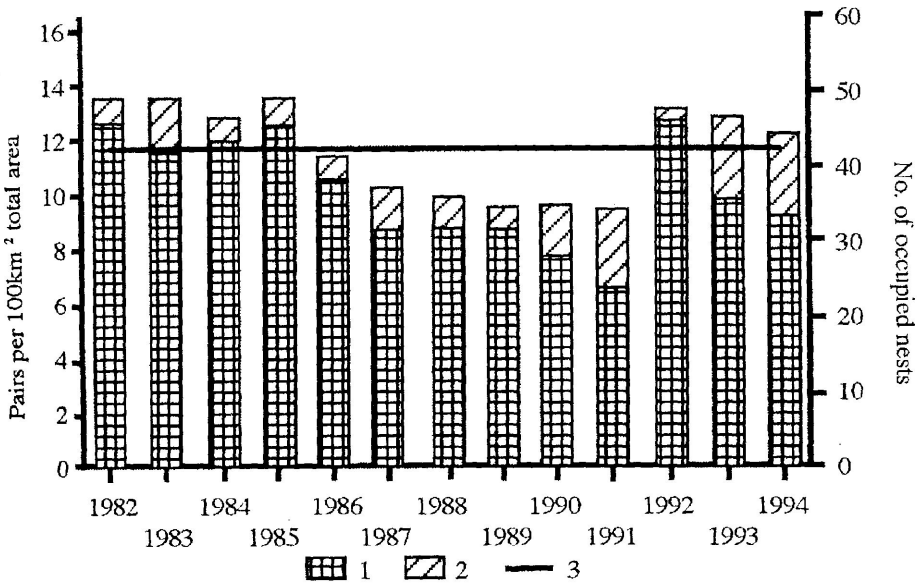
The Kampinoski National Park (20°18'-53'E, 52°16'-25'N) lies near the city of Warsaw, with its two-million human inhabitants. The Park covers an area of 35,482 ha, with 61% at the beginning and 71% at the end of the study consisting of forest, 12% of meadows, 5% of arable land and 12% of villages, roads and suburbs. Some 76% of the forest represents pine stands located on fluvio-glacial dunes and 24% represents mixed forests and alder swamps in the lowest parts of the area (elevation 67-95 m above sea level). The forest forms two discontinuous belts, with a total forest edge of about 250 km. In the vicinity, many small villages and farms provide plenty of food for Goshawks (domestic pigeons, poultry, etc.). Because the area is protected, the nesting habitat has changed little during the past 40 years (except 10% of newly afforested fields and meadows).

METHODS

In 1980-82 all big nests in the study area were located during winter. Since 1982, every March - April, all nest areas were checked for breeding pairs, and occupied nests were checked a second time during the fledgling stage in June. Besides inspection from the ground, about 20% of active nests with eggs and young were checked by climbing. Additional searching for new nests was undertaken each winter.

During 1982-1994, I found 72 nesting places each used for 1-13 years, and with 1-12 nests used at least once in that time. Every year most existing nesting places (about 70-90%) were occupied by Goshawks.

Fig.1 Changes in breeding numbers and densities of Goshawks in the Kampinoski National Park, Central Poland, in 1982 - 1994.



1) Certainly Occupied Breeding Territories - nests with eggs or young.
2) Probably Occupied Breeding Territories - nests not checked this year, but active in the preceding and following years.
3) Mean numbers 43.0, SD=6.1, or density 11.9 pairs per 100 km^2 in the total area.

RESULTS

In the period 1982-1994, I found each year from 35 to 50 (mean=43.0, SD=6.1) breeding pairs of Goshawks in this area (Fig.1). This corresponds to a density of 9.7-13.9 breeding pairs per 100 km^2 of total area, or 16-23 pairs per 100 km^2 of woodland. The mean nearest neighbour distance for the years of highest density (1985 and 1992) was 1660+86 m. Fluctuations from year to year did not exceed 16% of the mean value, which was 43 breeding pairs (the only exception was 1991-92 with numbers 37% below the mean, but also with higher proportion of unchecked nests in 1991). There was no difference between the mean number of breeding pairs in the first and second halves of the study period (in 1982-88, mean=44.9, SD=5.8; in 1988-1994, mean=40.3, SD=6.1; t=1.442, NS). The coefficient of variation (W=sqrt(v)/y, v=ns^2/(n-1)) was 15%. Regression analysis of the number of breeding pairs (y) against year (x) gave a slope not significantly different from zero (t=-1.26, p>0.05). These various data thus gave no evidence for a long term trend in numbers.

The correlation coefficient between the number of pairs in a given year

and the following year calculated for all the study years was 0.684 ($p<0.01$). If numbers recorded in 1991 are excluded as containing a possible greater error, the correlation coefficient increases to 0.898 ($p<0.001$). There is no correlation between numbers in a given year and numbers two years later ($r=0.324$, $p=0.33$).

To check for density dependent processes, I examined some reproductive parameters, such as mean clutch size, mean brood size, percent of successful nests and number of young per nest (y) in relation to numbers of breeding pairs the

Table 1 Breeding performance of Goshawks in the Kampinoski National Park.

	Clutches			*Fledglings*			
Years	*N*	*Mean clutch size*	*% of 2-egg clutches*	*N*	*Mean brood size at fledging*	*% of nests in which at least one youg fledged*	*Mean number of young per breeding pair 1/*
1982-1985	55	3,65	3,6	161	3,25	77,6	2,5
		*			*	NS	
1986-1991	54	3,31	14,8	144	2,75	77,8	2,1
		*			NS	**	
1992-1994	34	3,85	2,9	95	2,70	62,1	1,7
Total	143	3,54	7,7	400	2,91	76,5	2,25

1/ calculated from mean brood size and percent of successful nests. student test was used:
* - $P<0.05$, ** - $p<0.01$

Table 2 Nest failures among Goshawks in the Kampinoski National Park.

Years	*Number of nests checked*	*Complete failures*		*Partial failures*	*Overall failures*	
		%	*% due to human persecution*	*% of failures in nests which raised at least 1 young (N=57)*	*In nests checked twice (N=84)*	*Combined from complete and partial failures*
1982-1985	161	22,4	18	13,2	47,3	31,5
		NS	NS	NS		
1986-1991	144	22,2	14,6	19,8	30,9	36,6
		***	NS	NS		
1992-1994	95	37,9	22,1	23,1	61,5	55,8

Complete failures - failures of whole nests,
Partial failures - difference between N of fledglings and N of eggs in successful nests checked at least twice (N=57)
Overall failures - proportion of eggs which did not produce young.
χ^2/ test was used: *** - $p<0.001$.

same year (x), and found no significant correlation except between numbers and clutch size (r=0.696, p=0.008, regression: y=2.126+0.033x). However the correlation was positive, opposite to that expected under density dependence.

Three several-year periods could be distinguished during the study (Fig.1):

A. High numbers in 1982-85, corresponding to a mean density exceeding 13 pairs per 100 km^2,

B. Lower numbers in 1986-89, with densities of 8-11 pairs per 100 km^2,

C. Again high numbers in 1992-94, with densities exceeding 12.5 pairs per 100 km^2.

The data on reproduction and nest failures for these periods are shown separately in Tables 1&2.

Out of 483 occupied nests found in 1982-94, 143 were checked during incubation. The mean clutch size was 3.54, SD=0.30 (Tab.1) and fluctuated from year to year from 3.15 to 4.01, being significantly lower in the years of lower Goshawk density. The main reason for this was a much higher proportion of 2-egg clutches in this period.

Out of 483 nests found as occupied, 400 were checked at the fledgling stage, and from 306 (76.5%) one or more young flew. The proportion of successful nests fluctuated over the years and was lowest in the third (= latest) period (Table 1).

The mean number of young in successful nests in 1982-94 was 2.91, SD=0.29, fluctuating annually between 2.5 and 3.3. In the first period of higher Goshawk numbers, mean brood size was significantly higher than in other years (by 0.50 - 0.55 young per nest) (Table 1).

If we take into consideration active nests in which no young were raised, the number of young raised per breeding pair was then lower by 0.8 young in last period (mean=2.25, SD=0.33, range 1.7 - 2.7) than in the first.

Total nestling mortality was calculated as the sum of both total and partial nest failures (Tab.2). Complete nest failures were nearly 50% higher in last three years than in 1982-85 and 1986-91. This was not due to human persecution, which varied between the years, affecting from 3.8 to 26.8% of nests, but did not change significantly between the three periods. Partial failures could be estimated only from 57 successful nests that were checked at both egg and nestling stages. Differences between the three periods were not significant.

Despite some human interference, my study occurred during a period when the Goshawk was protected by law (since 1976). In the east part of the area, the Goshawk population was investigated 10-20 years before protection came in (Pielowski 1968), enabling a comparison between the two periods (Tab.3). On 20

Table 3 Comparison of Goshawk numbers and breeding performance in the Kampinoski National Park before and during a period of protection.

	*1956-1965 */*	*1982-1994*	*(p)*
Density per 100km² woodland area	25	26,5	
Mean clutch size	2,5	3,58	<0.01
% of 2-egg clutches	46	7,6	<0.01
N of clutches	124	142	
Overall failures at nest	50,8	42,8	NS
N of broods	124	84	
Mean N of young per breeding pair	1,2	2,25	<0.001

*/ Data from Pielowski (1968) from 23 km² of alderwood and mixed forest with small proportion of pine forest. This is one of the richest parts of my study area and optimal nesting habitat for Goshawk.

km², in the earlier study there were 5 pairs of Goshawk. In 1982 - 94 on the same area. I also found 5 - 6 pairs each year. In both periods there are similar overall failures at the nest, measured as the proportion of eggs which failed to produce young. However, the difference in mean clutch size was surprisingly large, which at the time before protection was lower by 0.7 - 1.35 eggs. At that time, the proportions of 2-egg clutches were much higher.

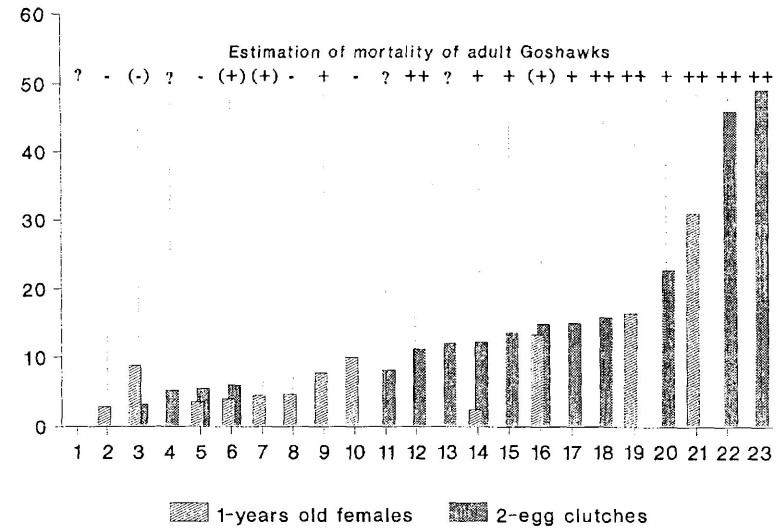
DISCUSSION

My data show one of the highest Goshawk nesting densities in Europe. If there are any errors in the figures, they can only be through underestimation of the number of breeding pairs. This might have occurred if there were new nests, destroyed very early in the season by human agency, or some nests difficult to gain access to, which were not checked in some years. Usually 5 - 15% of all previous nesting places were not checked in a given year, rising to 21-35% in 1991 and 1993-94.

Over the period 1982-94, no clear trends were observed in population size, although numbers were slightly lower for several years in the middle, and nest success was lower in the later years. Perhaps the Kampinoski National Park, being a protected area with a high proportion of forest, acts as a refuge for Goshawks, compared to surrounding small private woods, where many nests are still destroyed despite legal protection (unpublished data).

The numbers of pairs breeding in any given year explained 47% of the variance in numbers in the next year (or 81% if 1991 is excluded). More evidence of long term stability came from the comparison of density in 1982-94 with that in 1956-65 obtained by Pielowski (1968). The densities of 25.0 pairs per 100 km² of wooded area in 1956-65 and of 26.5 pairs in 1982-94 are almost identical. The comparison was made for a 23 km² area of optimum breeding habitat of Goshawks (mostly alder swamp and mixed coniferous forest with 100% of woodland), most

Figure 2 Proportion of 2-egg clutches and 1-year old breeding females in Goshawk in populations with different levels of adult mortality because of human persecution. Populations arranged in order of severity of persecution.



1 - S Poland, 1984-91 (Czuchnowski 1992), 2 - Russia-Ural, 1980-88 (Sepiel 1992), 3 - Central Poland, 1982-85 and 1991-94 (Olech, this study), 4 - Germany, before 1970 (Glutz 1971), 5 - E Poland, 1979-90 (Keller, unpubl.), 6 - Britain, 1965-80 (Marquiss & Newton 1982), 7 - Holland, 1972-79 (Thissen *et al.* 1982), 8 -Germany-Bavaria, 1975-79 (Link 1986), 9 - Germany-Bavaria, 1970-74 (Link 1986), 10 - Holland, 1979-88 (Bijlsma 1989), 11 -Czechoslovakia, before 1970 (Glutz 1971), 12 - Germany, 1858-1958 (Zang *et al.* 1989), 13 - Fennoscandia, before 1970 (Glutz 1971), 14 - SW Poland, 1993-95 (Adamski, unpubl.), 15 - Sweden, 1969-1981 (Wikman & Linden 1982), 16 - Central Poland, 1986-91 (Olech, this study), 17 - Bielorussia, 1946-1981 (Nikiforov 1989), 18 -Czechoslovakia, 1969-1983 (Divis 1984), 19 - Holland, 1969-1971 and 1980-81 (Thissen *et al.* 1982), 20 - Holland, 1973-78 (Bijlsma 1989), 21 - Germany-Bavaria, 1980-84 (Link 1986), 22 - Central Poland, 1956-65 (Pielowski 1968), 23 - Ukraina, 1900-1950 (Zubarowski 1977) and 1987-94 (Gorban, unpubl.)

Estimated human-induced mortality of Goshawks: - none, (-) probably none, (?) no estimate, (+) probably high, + high, ++ very high.

of which has been a strict nature preserve since 1936, subject to only slight changes over the period concerned.

No correlation was found between numbers of breeding pairs and reproductive parameters such as mean brood size at fledgling, proportion of successful nests and number of fledglings per breeding pair. This can be taken as lack of evidence for density-dependent regulation of breeding success. The significant positive correlation ($r=0.697$, $p<0.001$) between population density and clutch size requires a separate explanation.

The Goshawk, as an «indeterminate layer», lays from 1 to 5 eggs, most often 3-4 eggs per clutch. According to my experience, 1-egg clutches are mostly

replacements or remains after earlier losses during incubation, and 2-egg clutches belong mostly to 1-year old females. Unfortunately, too few females of known clutch size were aged to document this statement statistically.

There are, however, indirect indications. In some species of raptors young females lay smaller clutches (Newton 1979, 1986). Clutch size in the Goshawk is correlated with laying date (Huntala & Sulkava 1982) which in turn for many species (Lack 1966) including raptors (Newton 1976, 1979) depends on age, with young females laying later than older ones.

Furthermore, some authors noted that the proportion of young Goshawk females in the breeding population varies, being higher during periods of lower or declining numbers, accompanied with higher adult mortality (Thissen *et al.* 1982) or in populations under more intensive human persecution (Grunhagen 1983). In Germany in the years of high Goshawk numbers (1975-79) the proportion of 4-year old females was 4.8% (N=217), whereas in the period of low numbers (1980-84) it was as much as 22.7% (N=66) (Link 1986). A similar situation has been found in Holland, where during a decline in 1973-78, 1-year old females accounted for 31% of the female breeding population, but only for 10% in 1979-88 (Bijlsma 1989). The author ascribed this to reduced mortality of adults in the later period. The highest known proportion of breeding females in immature plumage is 67% in areas with high human persecution of adult birds (van Manen 1990 after Bijlsma 1991)

A comparison of the frequency distribution of clutch sizes between areas or periods with higher and lower human persecution (killing adult Goshawks) shows that the proportion of 2-egg clutches varies from 0% to 49%, and is higher where the killing of adults is estimated as high.

Almost certainly, then, the high proportion of 46% 2-egg clutches recorded in my study area by Pielowski (1968) reflected heavy persecution of Goshawks at that time, and a consequent high proportion of yearlings in the breeding population. A similar phenomenon, with up to 63% 2-egg clutches, occurs in a Ukrainian population of Goshawks (Zubarowski 1977, Gorban unpubl.), which is supposed to be under strong human pressure.

In many European countries, including Poland, in the first half of the 20th century, killing «hawks» was not only common, but was rewarded by payment of premiums, and legal protection of the species did not change attitudes immediately. Even now, Goshawks are still trapped and shot in Poland, though perhaps in lower proportion than before 1976. However, shooting was difficult in Poland in 1982-86 a period of martial law, when hunters had to deposit fire-arms, not retrieving them until 1986. This was probably the reason for the high density (over 13 pairs per 100 km^2 overall or 23 pairs per 100 km^2 wooded area) in the early 1980s. If this was followed by an immediate increase in shooting, it would have led to an increased proportion of young females breeding, as well as to the decrease of numbers below 11 pairs after 1986. The increase of breeding numbers after 1992 was connected

with the simultaneous increase of the area of optimal breeding habitat (forest in the age 60-80 years) in Kampinoski National Park from 4192 ha in 1977 to 5275 in 1991 and with the establishment of new breeding territories.

Therefore killing of adults is a factor which can influence the Goshawk population in double way: both directly and by lowering the mean clutch size.

CONCLUSIONS

Comparing the breeding population under a period of legal protection with beforehand, I found that:

1. Mean clutch size was higher by 0.8-1.4 egg per clutch, due to a lower proportion of 2-egg clutches.

2. Number of young produced per breeding pair was nearly twice as high (2.25 and 1.2 respectively).

3. Overall nest failures were fairly similar (43% and 51%).

4. All these changes, at the levels observed in 1982-94, had little influence on the density of nesting Goshawks, which at least in optimal biotopes of the protected area, was similar (26.5 and 25.0 breeding pairs per 100 km^2 wooded area) and apparently stable.

5. Because the rates of nest failure were not markedly different, persecution in the earlier period in the Kampinoski National Park probably affected mainly full grown birds.

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