

Regulation of Goshawk *Accipiter gentilis* breeding in Western Finland over the last 30 years

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ABSTRACT

The Goshawk population is stable in most parts of Finland. The breeding data for this study originate from two main regions in Western Finland in 1961-1991, in total 603 clutches and 861 broods. The laying begins yearly 12.4 - 8.5., regulated most clearly by temperature of February-April. The regional mean clutch sizes are 3.3 - 3.6, and have in 1963-91 been yearly 2.4 - 4.2. The early laid clutches are significantly larger than the later ones. The mean losses in successful broods are 0.52 young. The regional mean brood sizes have been 2.6 - 3.1. In 1967-91 17.0% of breeding attempts failed totally.

The four tetraonid species are the main prey, in spring 50-85 % of the number of prey in Western Finland. The tetraonid populations have a clear and simultaneous fluctuation, 6-7 years between peaks. The yearly changes in the clutch size of the Goshawk follow significantly the fluctuation of the total density of tetraonids. The positive correlation between the brood size in successful Goshawk nests and tetraonid density is significant too. The Red Squirrel is also a common prey of the Goshawk and has pronounced yearly changes in density, but has not any effect on the clutch or brood size.

INTRODUCTION

Breeding in birds of prey is generally regulated by prey availability, and in some cases also by climatic factors and physiologically by day length (e.g. Hagen 1969; Newton 1979, 1986; Huhtala & Sulkava 1981; Kostrzewa & Kostrzewa 1990, 1991; Dobler 1991). Where conditions have been altered by man, a lack of nest sites, poisons in food, nest robbing and indirect disturbance may be reasons for low breeding success (Fischer 1980; Newton 1986).

The Goshawk suffered a severe decline in the 1960s in Central Europe, but soon after the ban on a number of pesticides the populations increased in many areas, especially in the 1970s (Thissen *et al.* 1981; Storgård & Birkholm-Clausen 1983; Bijlsma 1991). The mainly introduced population in England also increased, especially during the 1980s (Anon. 1989).

Nesting results among the Goshawk population in Finland have remained fairly stable during the last 30 years (Saurola 1985; Korhonen & Saurola 1990), although a decrease was observed in

the extreme south of the country during the 1980s (Forsman & Ehrnstén 1985). There are also differences in nesting results between years, but the reasons are mostly natural ones (Sulkava 1964; Wikman & Lindén 1981). Direct human influence on breeding has not been dangerous for the Finnish Goshawk population (Haukioja & Haukioja 1970; Huhtala & Sulkava 1981).

This paper will present:

- some general facts on the breeding and diet of the Goshawk in Finland
- data on regulation of the onset of breeding by environmental factors and
- data on regulation of the clutch and brood sizes of the Goshawk in western Finland.

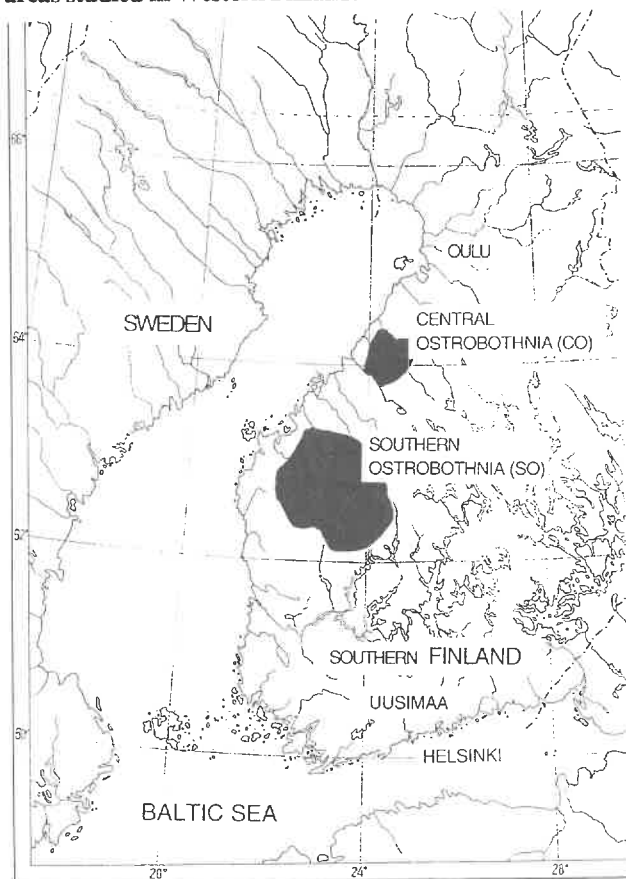
AREAS STUDIED

The material from western Finland originates from two main areas:

Southern and Central Ostrobothnia (Fig. 1, map). Southern Ostrobothnia is the main area studied by the Suomenselkä Ornithological Society, which has collected annual statistics on breeding in hawks and owls since 1967.

The smaller, and published, sets of material from southern Finland are available from three areas: near the town of Pori on the west coast (Hakila 1968), the inland province of Häme (Sulkava 1964; Kolunen 1987) and the western part of the province of Uusimaa in the extreme south (Wikman & Lindén 1981; Forsman & Ehrnstén 1985).

Figure 1. The areas studied in Western Finland.



GENERAL FACTS ON BREEDING AND DIET

The nesting season for the Goshawk in western Finland begins with nest-building, mostly in March. The eggs are laid during April. As an example, we show the beginning of nest-building and the onset of egg-laying in Central Ostrobothnia in 1966-77 (Fig. 4). The yearly changes are sometimes relatively large.

Mean clutch and brood sizes in Finland and Central Europe do not show any regular regional differences (Table 1), although the clutch size seems to be a little smaller in Northern Europe than in Central Europe. Relatively small clutch sizes seem to prevail in Southern Finland (and also in more northerly areas, e.g. near Oulu, 3.06, Tornberg & Sulkava 1990), whereas they are large in England.

Table 1. Clutch size and number of young of the Goshawk in some areas of Europe. Uusimaa, Finland (Solonen 1979; Forsman & Ehrnsten 1985); Germany (Fischer 1980; Glutz 1971; Dobler 1991; Möckel *et al.* 1987; Link 1977; Stubbe & Gedeon 1991); England (Anon. 1990).

Region, years	Clutch size			Large young /successful brood			Large young /clutch laid		
	Mean	S.E.	N	Mean	S.E.	N	Mean	S.E.	N
C. Ostrobothnia 1961-76	3.51	0.06	164	2.83	0.11	148	-	-	-
C. Ostrobothnia 1981-90	3.59	0.24	135	3.06	0.19	180	-	-	-
S Ostrobothnia 1971-80	3.44	0.15	122	2.74	0.15	158	2.17	0.17	204
S Ostrobothnia 1981-90	3.28	0.13	182	2.88	0.09	375	2.48	0.16	314
S Finland, Uusimaa 1962-84	3.08	0.13	89	2.63	0.11	135	-	-	-
Germany (publ. 1968-91)	3.64	0.06	132	2.51	-	430	1.73	-	466
England 1980-87	3.96	0.11	47	2.76	0.16	45	2.30	0.20	54

The nesting results of the Goshawk population seem to be the best in Western Finland (Ostrobothnia), however, and the poorest in Central Europe (Germany). The diet of the Goshawk in Finland differs greatly from that in Central Europe, where the main prey groups in the latter region are the Columbidae, Corvidae and Turdidae; the only important group in western Finland is the Tetraonidae (four species), with some squirrels and Corvidae. The tetraonids form the major prey both during nest-building and incubation in spring and during the nestling period in summer (Table 2). The spring food has been studied in both Central and Southern Ostrobothnia, and the percentage of tetraonids is large in both areas.

Table 2. Diet of the Goshawk in Central Europe (Brüll 1964 and Schnurre 1964, from Glutz *et al.* 1971) and in western Finland (Sulkava 1964 and Huhtala 1976).

	Central Europe	Western Finland	
		Spring	Summer
Grouse, Tetraonidae	-	68.1	46.4
Partridge, <i>Perdix perdix</i>	6.9	0.5	-
Doves, Columbidae	29.1	1.2	3.1
Crows etc., Corvidae	16.6	3.7	8.8
Thrushes and Starling, Turdidae and <i>Sturnus</i>	16.2	2.0	12.1
Rabbits and hares, Leporidae	9.2	0.1	0.3
Material, N	6378	2765	470

The diet during the nestling period has so far only been studied in detail (by accurate methods: direct observation from hides and the cage method) during the 1950s, in Southern Ostrobothnia (Sulkava 1964): The mean proportion of tetraonids in the nestling-time prey in 1954-58 was 53% (according to the prey numbers).

FACTORS REGULATING NESTING RESULTS

1. Changing prey availability

The densities of the main forms of prey in Finland, the four tetraonid species, fluctuate markedly and simultaneously (Fig. 2, Rajala & Lindén 1980). The effect of this main food on Goshawk breeding therefore differs from one year to the next.

2. Changing climatic conditions

The temperature in late winter and in spring could be important for breeding in Finland. Very cold weather in late winter may tax the energy reserves needed for breeding, and the rainfall in late spring or early summer could have some effect, as stated by Newton (1986) for the Sparrowhawk in England.

3. Natural enemies

(e.g. the Eagle Owl) and the direct or indirect impact of man could also detract from the nesting result.

REGULATION OF BREEDING UNDER VARYING CLIMATIC AND FEEDING CONDITIONS IN WESTERN FINLAND

Beginning of nest-building in Central Ostrobothnia

The building phase was checked at 3-5 Goshawk nests in one area in Central Ostrobothnia (by K. Huhtala) every weekend from late February onwards in 12 years (1966-77). The first twigs are often brought on the snow, which is often still present when nest building begins. The earliest occasions of beginning to nest were recorded in the last week of February and the latest in the first week of April. Building was often triggered off by the first warm days of the year (= above zero Celsius).

The mean onset of building is positively correlated with the mean temperature in February-March ($r = 0.668$, $P = 0.018$, Fig. 3), in that the building begins about one month later after cold winters than after warm ones.

REGULATION OF LAYING DATE IN CENTRAL OSTROBOTHNIA

The laying date is closely (and significantly) correlated with the date of the beginning of nest-building ($r = 0.753$, $P = 0.005$, Fig. 4), but its yearly variation is smaller (range 16 days, vs. 33 days in nest-building).

The midwinter temperature (mean temperature in January and February) also shows a significant correlation with the mean laying date ($r = 0.515$, $P = 0.050$, Fig. 5), which means that cold winters delay laying.

The direct correlation between laying date and mean late winter temperature (mean of February-March, which was stated above to be significantly correlated with the date of nest-building) is also obvious, but not significant ($r = 0.393$, $P = 0.21$), as is the correlation between laying date and the temperature in April (the laying month).

The laying date could also be regulated by the availability of prey (food) as is seen in some owls (e.g. Tengmalm's Owl, Korpimäki 1986).

In the Goshawk, however, it does not correlate significantly with the density of tetraonids or the yearly percentage of tetraonids in the diet. It seems, therefore, that food (prey) does not regulate the laying date of the Goshawk in western Finland, where it is most powerfully regulated by the temperature in late winter (February-March).

Figure 2. Fluctuations in the four tetraonid species, Capercaillie (*Tetrao urogallus*), Black Grouse (*Tetrao tetrix*), Hazel Hen (*Bonasia bonasia*) and Willow Grouse (*Lagopus lagopus*) in western Finland (Southern Ostrobothnia) in 1964-91 according to the Finnish Wildlife Research institute.

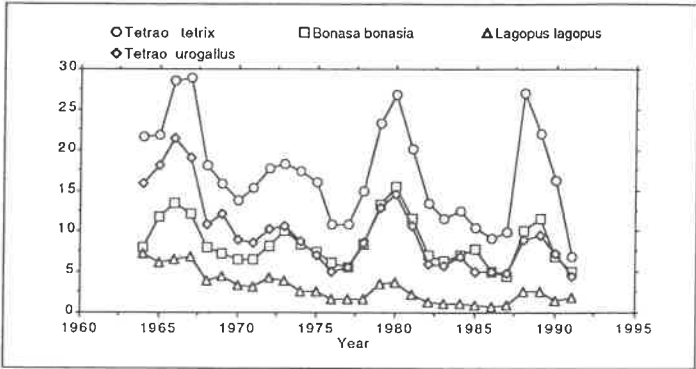


Figure 3. Correlation between the mean date of the beginning of nest building by the Goshawk in March in Central Ostrobothnia in 1966-1977 (18 years) and mean temperature in February-March ($r = 0.668$, $P = 0.018$).

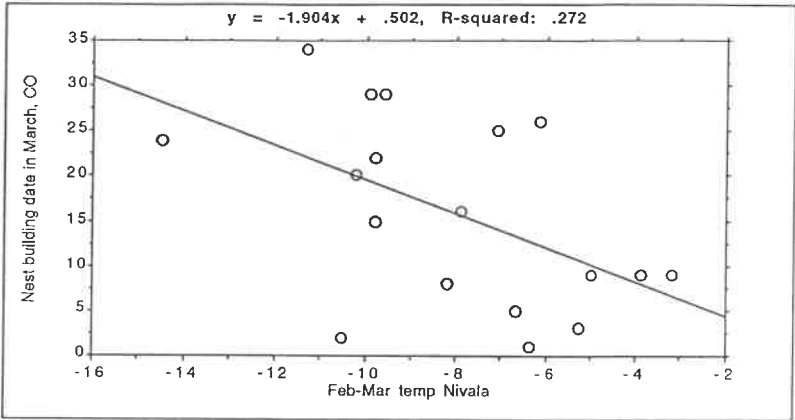


Figure 4. Correlation between the mean date of the beginning of nest building by the Goshawk in Central Ostrobothnia in 1966-77 (17 years) and mean laying date ($r = 0.753$, $P = 0.005$).

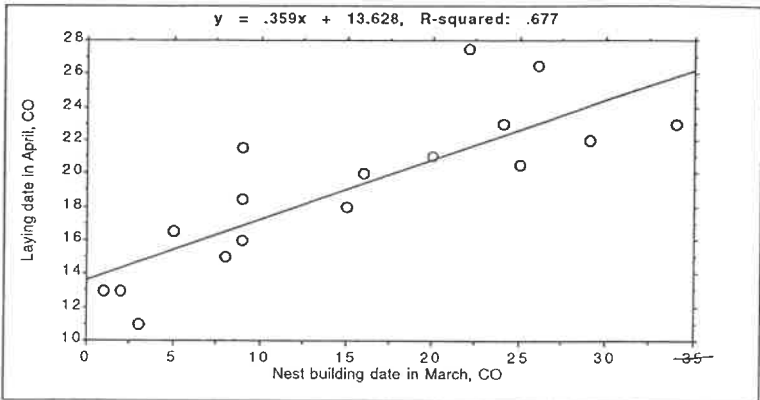
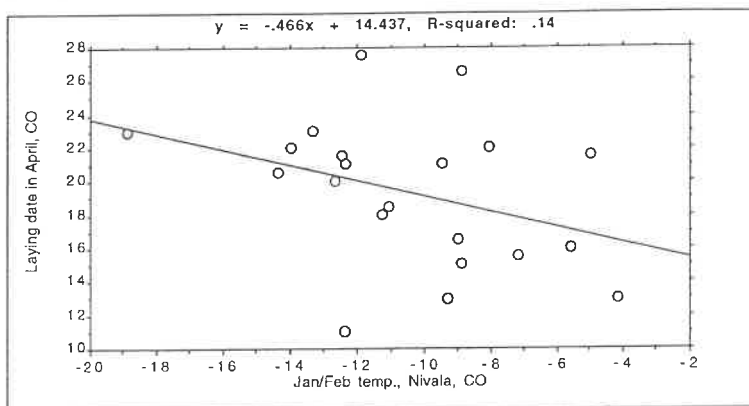


Figure 5. Correlation between midwinter temperature (January and February) and the laying date of the Goshawk (in April) in Central Ostrobothnia in 1963-77 (21 years, $r = 0.515$, $P = 0.050$).



REGULATION OF CLUTCH SIZE

Clutch size and laying date show the normal correlation: i.e. later clutches are highly significantly smaller (yearly means in Central Ostrobothnia 1963-77, $r = -0.898$, $P < 0.001$, Fig. 6).

It is well-known that some owls (e.g. Tengmalm's Owl) lay earlier and larger clutches in good vole years, and that changes in food produce corresponding changes in the clutch size in owls (Korpimäki 1981). The Sparrowhawk in Great Britain has been observed to lay significantly earlier and larger clutches with additional feeding (Newton 1986).

In the Goshawk the corresponding changes could be caused by changes in the density of tetraonids, which are their main food in western Finland. This relationship had already been observed in the 1950s in Southern Ostrobothnia (Sulkava 1964), although information on fluctuations of tetraonids was less accurate prior to 1963 (See Rajala 1974).

The correlation between tetraonid density and the clutch size of the Goshawk over the last 30 years is shown below for Southern and Central Ostrobothnia.

In Southern Ostrobothnia clutch size since 1966 has mostly been larger in better tetraonid years (Fig. 7), the correlation being significant ($r = 0.421$, $P = 0.036$), although it explains only 18% of the variation in clutch size.

A weak and non-significant correlation also exists between March and April temperatures and the clutch size of the Goshawk in Southern Ostrobothnia in 1967-91 ($r = 0.22$ and 0.21), and the correlation with January-February temperatures is still weaker ($r = 0.17$). The combined correlation of temperatures in different months and the combined effect of temperature and tetraonid density were also checked, but they did not improve the correlations.

In Central Ostrobothnia the positive correlation between clutch size and tetraonid density in the previous August is also significant (Fig. 8, $r = 0.429$, $P = 0.026$), the clutch size being larger in better tetraonid years.

Even so, midwinter temperature still has a clear effect on the clutch size, and the correlation between mean January-February temperature and mean clutch size (in 1963-91) is significant ($r = 0.424$, $P = 0.022$, Fig. 9). March and April temperatures have corresponding but weaker and non-significant correlations with clutch size.

The yearly relationship between clutch size in the Goshawk and populations of the Mountain Hare and Red Squirrel were also analysed (using population indices from Finnish Wildlife Research Institute), but these prey species had no significant effect on clutch size.

Figure 6. Correlation between the mean clutch size of the Goshawk in Central Ostrobothnia in 1963-1991 (21 years) and the mean date of laying the first egg ($r = 0.911$).

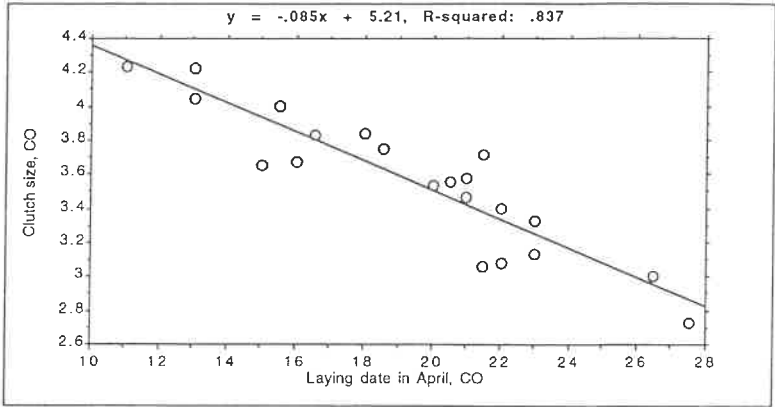


Figure 7. Yearly changes in the clutch size of the Goshawk and the total density of tetraonids (ind./km2, in August of the previous year) in Southern Ostrobothnia in 1967-91 (25 years). (Correlation: $r = 0.421$, $P = 0.036$).

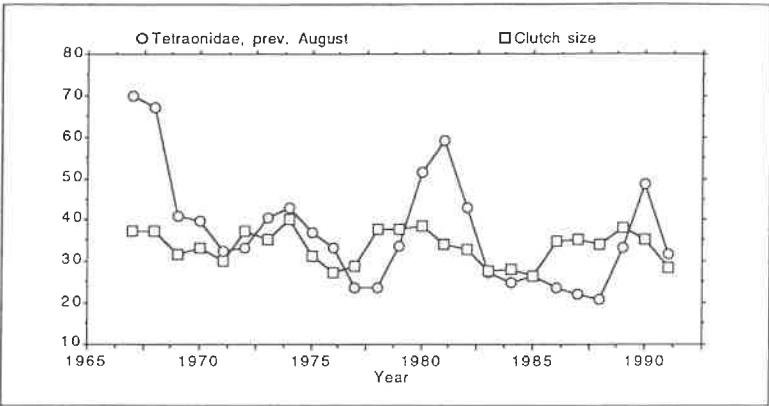


Figure 8. Correlation between the clutch size of the Goshawk and the total density of tetraonids (ind./km2, in August of the previous year) in Central Ostrobothnia in 1964-91 ($r = 0.429$, $P = 0.026$).

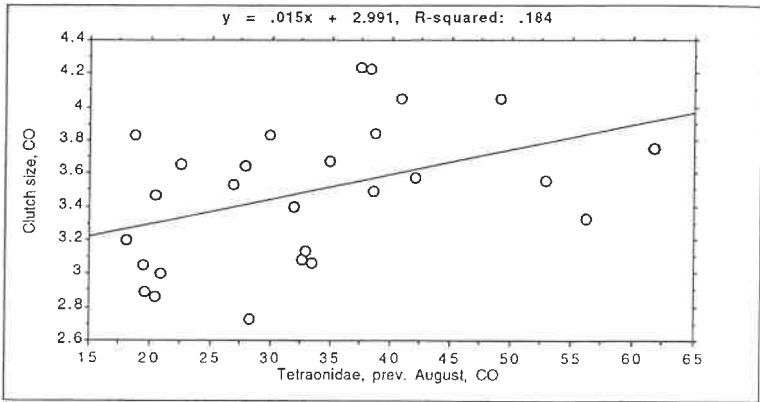
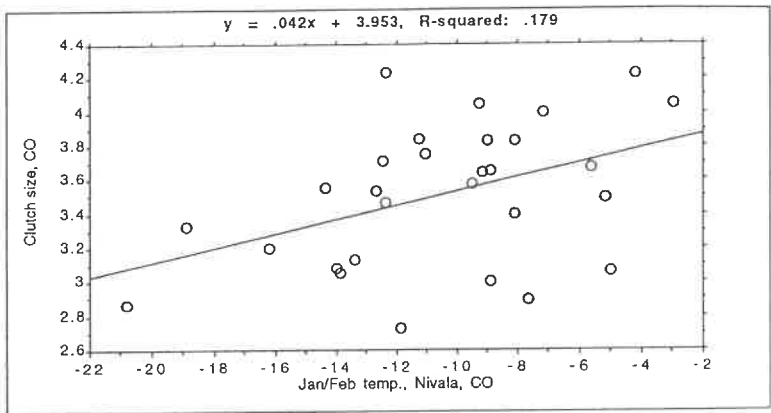


Figure 9. Correlation between the clutch size of the Goshawk and midwinter temperature (mean of January and February) in Central Ostrobothnia in 1963-91 (29 years, $r = 0.424$, $P = 0.022$).



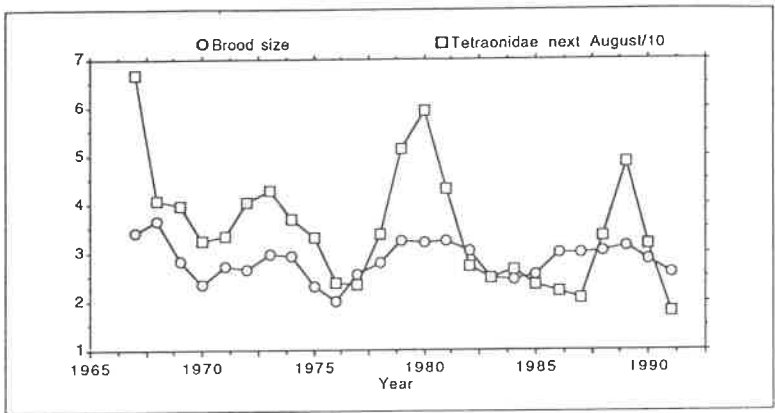
REGULATION OF BROOD SIZE

The tetraonid prey is also very important for the Goshawk and its young in summer (Table 2). The density of tetraonids in the field (adults + their young = availability of food for the young of the Goshawk) could therefore regulate the brood size of the Goshawk in western Finland.

In Southern Ostrobothnia (the area of the Suomenselkä Ornithological Society, Fig. 1) the positive correlation between the yearly changes in brood size (large young) of the Goshawk and total tetraonid density (the next August; years 1967-91) is highly significant (Fig. 10, $r = 0.623$, $P < 0.001$), the brood size of the Goshawk being larger in good tetraonid years than in poor ones.

The brood size is, of course, highly significantly correlated with clutch size in spring ($r = 0.726$, $P < 0.001$): so that if the clutches are larger, the broods are mostly larger too, and it is therefore also affected by the factors mentioned above, as regulating clutch size (e.g. temperature and availability of prey in late winter).

Figure 10. Yearly changes in the brood-size (large young) of the Goshawk and the total density of tetraonids (ind/km2, in August of the same year) in Southern Ostrobothnia in 1967-91 (25 years, correlation: $r = 0.623$, $P = 0.001$).



Nestling losses (deaths mostly during the early nestling period; yearly means are 0.4-0.7 young per nest) have only slight and non-significant correlation ($r = 0.25$) with the density of tetraonids in early summer (in fact in the previous August) before the young of tetraonids appear in late June. In large clutches (4-5 eggs) the last egg often hatches 1-2 days later than the others and this last nestling often disappears soon afterwards (Sulkava 1964), even in good food years. The number of rainy days (over 1 mm) in May and June similarly did not have any correlation with the nestling losses in Southern Ostrobothnia in 1967-91.

It may be concluded from the significances of the correlations for Southern Ostrobothnia that the brood size of the Goshawk is more affected directly by clutch size than indirectly by tetraonid density in summer, and that nestling losses are affected more by clutch size than by prey availability in summer. The clutch size is also regulated by tetraonid density, however, which emerges as the main factor.

In Central Ostrobothnia the effect of the total tetraonid density on the brood size of the Goshawk in 1964-85 is also obvious, but not significant. The correlation is significant ($r = 0.377$, $P = 0.44$) only with the main tetraonid species in the diet, the Black Grouse (*Tetrao tetrix*).

CONCLUSIONS

The obvious stability of the Finnish Goshawk population over the last 30 years (Saurola 1985; Korhonen & Saurola 1990) is somewhat difficult to explain, for several reasons:

- nest-robbing and shooting have probably decreased since the 1970s, because the Goshawk has been protected during the nesting season since 1979 (extended to a longer nesting period, April to July, in 1983) and the whole year round since 1989.

- the earlier killing of young and adult Goshawks was obviously not very dangerous to the population, however, because it was mostly only the "surplus" population that was killed and the adult birds became more careful and silent at their nesting sites (Haukioja & Haukioja 1970).

- tetraonids - the main prey - have decreased during the last thirty years, but the Goshawk and its nesting results have generally not (with the exception of a local decrease in the extreme south of Finland, Forsman & Ehrnsten 1985).

- environmental factors, e.g. temperature and availability of food, do not change simultaneously and therefore cause different changes in nesting results and population density.

The future of the Goshawk population in Finland seems to be dependent on the success of the tetraonid populations in the forests. The local decrease in the south of the country during the 1980s mentioned above already suggest that the decrease in tetraonids in Finland may later cause a more general decrease in the Goshawk population. The tetraonids, for their part, are dependent on the forestry measures and hunting practices.

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