Activity patterns and time-budget in the Goshawk *Accipiter gentilis* in a boreal forest area in Sweden

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The activity pattern and time budget of goshawks were studied during January and February 1980 and 1981 in a boreal forest area in southern central Sweden. Flights were of short duration (median 24 s), separated by longer periods of non-flight (median 3 min). Males spent more time per day flying than did females, 7.1 % of the daylight period compared with 6.5 % for females. Male flight activity was evenly distributed throughout the day; females showed a peak during the morning, coincident with the activity of their main prey, squirrels. The goshawks responded to increasing hunger with increasing flight activity. This was due to the hawks flying more often, whereas the duration of the flights remained the same. It is suggested that goshawks in boreal forests may hunt in a different manner from goshawks in more open habitats, having a generally higher prey density.

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Introduction

Nearly all studies of the foraging behaviour, diel activity patterns and time and energy budgets of birds of prey concern easily observed species, hunting in open habitats where they can be directly observed for long periods of time (Warner & Rudd 1975, Tarboton 1978, Wakeley 1978a, b, c, Sylvén 1982, Rudolph 1982). Compared with many other raptors, the forest-living Goshawk *Accipiter gentilis* is a bird of secretive habits, and a difficult subject for studies of hunting behaviour, time budget and activity pattern. Accordingly few studies of its habits are available. Erzepky (1977) and Hantge (1980) observed the hunting techniques and hunting success of goshawks in open country. Kenward (1982) described the hunting behaviour and activity pattern of released, partially tamed, goshawks in an area of England with 8 % scattered deciduous woodland, using radio telemetry to locate the hawks. However, coniferous forest prevails in most of the goshawk's breeding range. In this habitat lengthy observations of the hawks are practically impossible, and as a result data about its hunting behaviour, time budget and diel activity pattern in boreal forests are lacking.

The objective of this paper is to present and discuss information on the activity pattern and time-budget of free-living goshawks during winter in a coniferous forest habitat in central Sweden. Preliminary data from the study, especially concerning the radio-monitoring technique, have been briefly presented elsewhere (Widén 1981, 1982a).

Material and methods

The field work was carried out around Grimsö Wildlife Research Station in southern central Sweden (59°25'N, 15°25'E), in the southern boreal forest zone (Sjörs 1965). The area is fairly flat with an altitude of 75—150 m above sea level. Its main vegetation is coniferous forest (74 % of the total area) with Scots pine *(Pinus sylvestris)* and spruce *(Picea abies)*, sometimes with an admixture of deciduous tree species, such as birch *(Betula* spp) and aspen *(Populus tremula)*. Wetland, both peat bogs and fens, comprise 18 % of the area. Lakes and rivers form 5 % of the area, while only 3 % is farmland. For a more detailed description, see Cederlund et al. (1980).

Goshawks were trapped in box-traps using live pigeons as bait, and were equipped with tail-mounted radio-transmitters, as described by Kenward (1978) and Widén (1982a). Signals were recorded on a paper chart recorder (see Widén op. cit. for further details). Records were classified as either flight or non-flight (including activity-in-place, such as eating and preening, as well as resting). It was not possible to make further distinctions between different kinds of activity. Flight activity periods shorter than 12 s could not be distinguished from consecutive inactivity and may have been overlooked. Inactivity could not be determined for uninterrupted periods shorter than 48 s, and shorter periods therefore had to be included in preceeding and succeeding activity. Some short periods of inactivity may therefore have been treated as flight activity. The activity of eight goshawks, four males and four females, was recorded between 10 January and 3 March in 1980 and 1981, for a total of 1015 hours (42 days).

To test how increasing hunger influenced the behaviour of the goshawks, their activity patterns and time-budgets were measured in relation to preceeding food intake. Since this required continuous activity recording simultaneously with continuous monitoring of the predation, which was difficult to achieve, this part of the material is smaller, consisting of activity data from three different goshawks and 16 kills. Predation was recorded

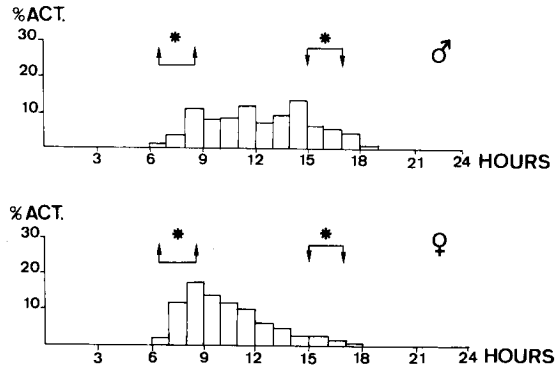

Fig. 1. Proportion of time spent flying per hour during the period 10 January to 3 March, for male and female goshawks.

by tracking the hawks and approaching them on kills (Kenward 1980, Widén 1982b). Activity recording began immediately after consumption of a kill, and continued until the next kill. The main prey taken by the goshawks during the study period were squirrels *Sciurus vulgaris*, weighing 250—300 g, which is about sufficient to fill a goshawk's crop.

Results

In total, male goshawks were flying 4 % of the time, which was slightly but significantly more than females, which were on the wing 3.5 % of the time (χ^2 = 79.5, P<0.001). The males' higher activity over the 24 h period was partly due to their roosting later in the evening, on average 26 min after sunset, compared with 26 min before sunset for females (P<0.001, Mann-Whitney U-test). This difference was not compensated for by the females' tendency to leave the roost somewhat earlier than males, 27 and 21 min before sunrise respectively (NS, Mann-Whitney U-test). Males were significantly more active than females also after excluding the roosting period (7.1 % and 6.5 % respectively, χ^2 = 17.9, P<0.001). Male flight activity was fairly evenly distributed over the non-roosting period (Fig. 1). Females, on the other hand, had a peak in flight activity between 8 and 9 a.m., when they flew for 17.3 % of the time. Flights were of short duration, separated by long periods of inactivity. Inter-perch flights averaged 84 s for males and 96 s for females, but the distribution was skewed towards shorter periods, the median period length measuring 24 s for both males and females. Periods of inactivity averaged 8 min 36 s for males and 10 min 24 s for females, again with a skew towards shorter periods, the median inactivity period length being 3 min for both males and females.

The flight activity of the goshawks increased with increasing hunger (Fig. 2). On the same day as a kill was made it was 3.0 %, on the next day 5.7 %, and on the second day after a kill 9.1 % (χ^2 = 145.0, P<0.001). In all cases except one, the goshawks had made a new kill within two days. Fig. 3 shows that the increased activity was due to shorter inter-flight periods, i.e. the hawks stayed perched for shorter periods. On the same day as a kill had been consumed, the median inter-flight period was 7 min (average 30.8 min), on the next day 4 min (average 12.4 min), and on the second day 3 min (average 9.8 min). The difference between day 0 and 2 was statistically significant (median test, P<0.05). The duration of the flights remained the same (median 24 s), but they occurred more frequently. In two cases the

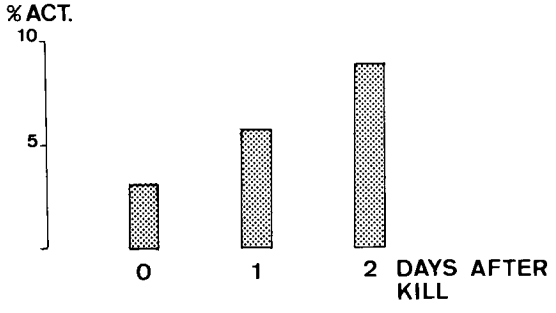

Fig. 2. Proportion of time spent flying per day after last food intake.

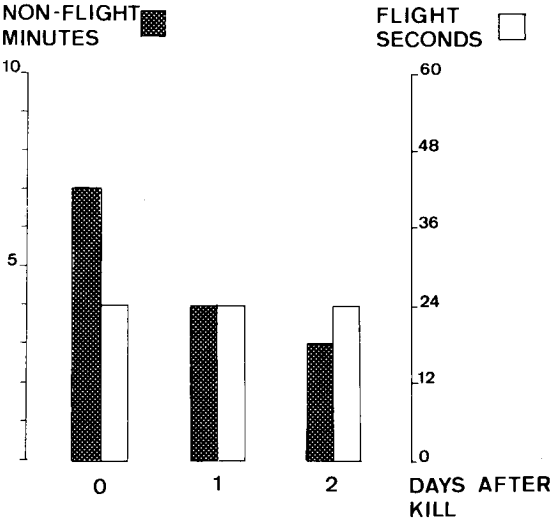

Fig. 3. Median duration of periods of flight and non-flight per day after last food intake.

hawks killed prey large enough to last for more than one meal (Mountain Hare *Lepus timidus* and Capercaillie *Tetrao urogallus)*. The hawks fed on these kills on two or three consecutive days, with little activity between feeding. These cases have been excluded from the analysis.

Discussion

Hunting goshawks are usually described as attacking from short distances, either from a perch or approaching low over the ground, taking the prey with surprise, usually in thick cover (e.g. Brown 1976, Brüll 1977). In open country goshawks have been observed to use other techniques, sometimes attacking flying birds in the open after a long dive (e.g. Erzepky 1977, Hantge 1980). Kenward (1982) studied the hunting behaviour of released, partially tamed goshawks in an open agricultural area with scattered woodlands in England, and described their hunting technique as "short-stay perched-hunting". The goshawks made short movements between perches, and nearly all observed attacks were launched straight from a perch. They had a median flight interval of 4 min, and flights on average covered 100 m in woodland and 200 m in open country. Wild goshawks in agricultural areas in Sweden had a median flight interval of 3 min, which is significantly shorter than in England (Kenward 1982). The duration of flights was not recorded. The median interflight intervals for my goshawks in a boreal forest was 3 min, the same as Kenward (op. cit.) recorded in agricultural areas in Sweden. With a flying speed of 10—15 m/s the flight times recorded at Grimsö correspond to flight distances 2—3 times longer than those measured in England.

The area surveilled from one perch can be considered as a patch (Rudolph 1982), and the time the hawk stays there as the giving-up time for that patch. Charnov (1976) predicted that an optimal predator should leave a patch when, as a result of the patch being depleted by the predator, the expected return rate for the patch drops to a level equal to the habitat as a whole. Goshawks captured prey only in a few of the patches they visited. The expected gain from a patch should decrease from a maximum (when they enter the patch) with increased time spent in the patch, and thus after some period of time fall below the expected gain of moving elsewhere, even if the hawk itself does not reduce patch-quality. However, the patch may also be depleted by the goshawk's presence there, namely if it alerts the prey and thus makes it less accessible, even if it does not kill anything. The longer the hawk stays in the patch, the more likely it is to be discovered by its potential prey, thus reducing the expected gain from staying there.

Available data indicate that the flight times, i.e., travel times between patches, are longer for goshawks in boreal forests of Sweden, as compared to open woodland habitats in England. This may reflect a difference in prey density, the good patches being fewer, and thus further apart, in Swedish boreal forests. The data also indicate somewhat shorter giving-up times for goshawks in Sweden than in England. This is not consistent with theories of optimal foraging, since increased travel costs will reduce the profitability of moving to another patch, and thus will influence the decision as a factor increasing the giving-up time (Charnov 1976). It also contradicts the predictions from optimal foraging theory (e.g. Krebs et al. 1974) that giving-up times should be longer in poor habitats.

However, goshawks in boreal forest may hunt in a different manner than in more open habitats. Perhaps in a coniferous forest perched-hunting is less efficient than in deciduous woodland after leaf-fall, due to the denser cover and thus reduced visibility, as well as lower prey density, in the coniferous forest. Flying through the forest, flushing the prey by surprise, may be a more efficient hunting technique in this habitat. The time spent perched then would not reflect giving up time in that patch, but rather time used for resting between foraging flights.

My data show that goshawks respond to increasing hunger by moving more often, the result being an increase in total flight activity. If the majority of the attacks were launched from a perch, as Kenward (1982) reported for released hawks in England, this would be difficult to explain. If, however, goshawks in boreal forests hunt in a different manner, relying more on hunting "on the wing" and not so much on perched hunting, as tentatively suggested above, the increased flight activity can be interpreted as a result of increased foraging time, as reported for White-tailed Kite *Elanus leucurus* (Warner & Rudd 1975). A positive relationship between hunting effort and food deprivation in birds of prey was also reported by Mueller (1973), and Rijnsdorp et al. (1981).

An optimally foraging predator should concentrate its daily hunting activity to periods when the most important prey are most accessible. During winter, squirrels were the main prey for goshawks in my study area. Females had a somewhat higher proportion of squirrels in the diet than males (Widén, in prep.). In winter, especially in cold weather, the activity of squirrels is mainly confined to a concentrated feeding bout in the morning (Lemnell, pers. comm.). This is the period when they are vulnerable to goshawk predation. Probably female goshawks were more active than

males in the morning because squirrels were a more important component of their diet than for the males.

The material was collected between 10 January and 3 March. No nestbuilding or other indications of breeding activity was observed before late March. Nevertheless, some courtship activity may have been initiated earlier, without being observed. This may have contributed to males being more active than females. However, the males also had a higher relative food intake (weight of food/day as a percentage of the weight of the hawk) (Widén, in prep.), indicating that they were in fact hunting more intensively than the females. Males were also active later in the afternoon, although all kills recorded during winter (Widén, in prep.) were made between 8.00 and 15.00, the majority (77 %) before 12.00. This could be due to the males performing other types of flight activity, such as circling or exploration flights. However, the length of flight periods do not suggest that the males performed such flights more often than females.

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Selostus: **Kanahaukan aktiivisuudesta ja aikabudjetista Keski-Ruotsin metsissä**

Kanahaukan talvista aktiivisuutta ja aikabudjettia tutkittiin tammi-helmikuussa vuosina 1980 ja 1981 Grimsön riistantutkimusaseman ympäristössä Keski-Ruotsin eteläosissa. Tutkimusta varten oli kahdeksan kanahaukkaa (4 ♂♂ ja 4 ♀♀) varustettu radiolähettimillä. Signaalien perusteella voidaan selvittää, milloin haukka on lennossa ja milloin se istuu paikallaan. Keskimääräinen lennossaoloaika oli varsin lytyt (24 sekuntia) ja lentojen välinen aika oli selvästi pitempi (3 minuuttia). Koiraat viettivät päiväsaikaan siivillään merkitsevästi pitemmän ajan kuin naaraat; koiraat olivat lennossa 7.1 % ja naaraat 6.5 % valoisasta ajasta. Koiraiden lentoaktiivisuus jakautui tasaisesti koko päivän osalle, kun taas naaraiden aktiivisuushuippu osui aamuun, jolloin myös oravat — päänavinto — olivat aktiivisimmillaan. Lisääntyvä nälkä kohotti lentoaktiivisuutta (kuva 2), mikä ilmeni useammin tapahtuvina lentoina lentoajan kuitenkin pysyessä samana (kuva 3). Näyttää siltä, että metsäisen Ruotsin kanahaukkojen lentoaika olisi pitempi kuin Englannin avoimemmassa maastossa metsästävien haukkojen. Tämän arvellaan johtuvan eroista saalistiheyksissä.

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