Home range, habitat selection and behaviour of male Eurasian kestrels (*Falco tinnunculus*) in boreal forest.

Hjemmeområde, habitatseleksjon og adferd hos tårnfalkhanner (*Falco tinnunculus*) i barskog.

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PREFACE

Studying the Eurasian kestrel has given me many fantastic days in the nature in Trysil and the whole process making this thesis has been very instructive and useful. Thanks goes to Bjørn E. Foyn and Ole Petter Blestad for letting me use their nest box sites for trapping of the kestrels. I would like to thank my supervisor Geir A. Sonerud for helpful supervising during the whole period, and Ronny Steen for good help during the field work and valuable comments on the manuscript. I also want to thank Terje Gobakken for his kindness in answering my questions about GIS.

My thesis was financially supported by Direktoratet for Naturforvaltning and thanks goes to them. Further I want to thank Henriette Ludvigsen for cooperation during the first week of the field work and Gunnar C. Nyhus for introducing me to radio telemetry in the field. I also want to thank Barbi Nilsen at Norsk institutt for skog og landskap for supplying me with the digital map and my employer during summer 2008, Joar Løken AS, for letting me manage my working hours quite freely during the field work.

Finally I want to thank my fellow students in the reading room for good company, Marte Løken for proofreading, and Ingvild Torsdal for reading through the manuscript and also pushing me to further effort in periods when the motivation was low.

Norwegian University of Life Sciences, 2009.

Øivind Løken

ABSTRACT

I used radio telemetry to study home range, habitat selection and behaviour of three male Eurasian kestrels (*Falco tinnunculus*) in boreal forest in Trysil, south eastern Norway, during the breeding season 2008. From a total of 32, 52 and 46 locations of the three kestrels I found that the size of their 100% minimum convex polygon (MCP) home ranges were 0.81, 2.23 and 3.55 km^2, respectively. This is quite similar to the findings in the only other study of home range size in kestrels. Small mammals were trapped in each home range, and home range size was inversely related to the trapping index of *Microtus* voles, which are the most important prey of kestrels. This is also in accordance with other studies. The three male kestrels preferred the habitat types bog and bog with forest and they used clear cuts (forest age class 1) more than older forest. On several occasions I also observed the kestrels hunting in selection felling areas. Based on my findings I suggest that kestrels would benefit from modern forestry. Mean fright distance was 75 m and fright distance increased with increasing proportion of bog within 25 m from the perch where the kestrel was located, and with increasing distance to the nest. Mean perch height was 18 m. None of the variables tested could explain the perch height, but the kestrels seemed to always choose the highest available perch. Solar height was the only variable found to explain whether a kestrel was perching or hovering.

SAMMENDRAG

Jeg brukte radiotelemetri til å studere hjemmeområde, habitatseleksjon og adferd hos tre tårnfalkhanner (*Falco tinnunculus*) i barskog i Trysil, sørøst Norge, i hekkesesongen 2008. Fra totalt 32, 52 og 46 lokaliseringer av de tre tårnfalkene fant jeg at størrelsene på 100 % minimum convex polygon (MCP) hjemmeområdene var 2.23, 0.81 og 3.55 km^2. Dette er ganske likt det som ble funnet i det eneste andre studiet på hjemmeområdestørrelse hos tårnfalk. Fellefangst av små pattedyr ble utført i hvert hjemmeområde, og størrelsen på hjemmeområdet var omvendt avhengig av fangstindeksen på *Microtus* som er det viktigste byttedyret for tårnfalk. Dette er også i samsvar med andre studier. De tre tårnfalkhannene foretrakk habitattypene myr og myr med skog og de brukte hogstflater (hogstklasse 1) mer enn eldre skog. Ved flere anledninger observerte jeg også at tårnfalkene jaktet i områder der det var drevet plukkhogst. Basert på mine funn foreslår jeg at tårnfalken vil kunne dra nytte av moderne skogbruk. Gjennomsnittlig fluktdistanse var 75 m og fluktdistansen økte med økende andel myr innen 25 meter fra det punktet falken ble lokalisert, og med økende avstand til redet. Gjenomsnittlig sitthøyde var 18 m. Ingen av variablene som ble testet kunne forklare sitthøyden selv om det virket som om tårnfalkene alltid valgte det høyest mulige punktet å jakte fra. Solhøyden var den eneste variabelen som kunne forklare om en tårnfalk jaktet fra en utkikkspost eller rytlet.

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INTRODUCTION

Burt (1943) defined home range as the area used by an animal for its normal activities, such as food gathering, mating and caring for young. Animals do not have their own home range until they have established themselves in an area and areas used by young animals in the seek of a ”home” cannot be called their home range (Burt, 1943). Both Burt (1943) and Mohr (1947) claimed that neither occasional sallies nor exploratory excursions outside the normal home region should be considered part of the home range. Animals may have different home ranges at different seasons and during the course of their lives (Mohr, 1947). The size of the home range often shows a strong positive relationship to the body size of the animal, and predators tend to have larger home ranges than omnivores and herbivores (Schoener, 1968).

The vole cycle in the northern hemisphere (usually 3-4 year cycles) (Henttonen et al., 1989) is causing varying food availability from year to year for animals dependent on small mammals (Cramp and Simmons, 1980; Korpimäki, 1994) and this may also affect home range size. Habitat is also a very important factor in describing an animals behaviour or space use (Southwood, 1977) and the spatial distribution of preferred habitat would most likely affect home range size as well.

My main questions in this study was to find out how large home range male Eurasian kestrel (*Falco tinnunculus*), hereafter called kestrel, use. And by doing so, also to study aspects of their behaviour and habitat use. There are some radio telemetry studies on home range in raptors (e.g. Call et al., 1992; Marzluff et al., 1994; Fredriksson, 2008), but to my knowledge only one radio telemetry study is carried out on home range in kestrels (Village, 1982a). This study was carried out in south Scotland, hence little is known about the kestrels home range in Scandinavia. Behaviour (e.g. Village, 1990; Deerenberg et al., 1995) and habitat use (Valkama et al., 1995) in kestrels have been studied more frequently.

The kestrel is a medium sized falcon occurring in most parts of Europe, Asia and parts of Africa (Cramp and Simmons, 1980; Tømmeraas, 1994). It is the most widespread, and often most abundant diurnal bird of prey in west Palearctic (Cramp and Simmons, 1980) and is probably the worlds most numerous falcon (Peterson, 2001). It is migratory in northern and eastern parts of its range, but is only partially migratory, or resident further south (Cramp and Simmons, 1980). In Norway the kestrel is nesting in most parts of the country, with emphasis on southern Norway (Tømmeraas, 1994). Winter range for the kestrels breeding in Norway are mostly western Europe (Tømmeraas, 1994), but they can also travel as far south as northern parts of Africa (Cramp and Simmons, 1980; Peterson, 2001). It can use a wide range of different habitats (Cramp and Simmons, 1980), but they are predominantly open-country birds (Village, 1990). There are approximately 3000 breeding pairs of kestrel in Norway (Tømmeraas, 1994; Peterson, 2001).

The kestrel feed mainly on small mammals, especially voles (*Cricetidae*) (Cramp and Simmons, 1980; Village, 1990; Fargallo et al., 2003), but may also feed on lizards (*Zootoca vivipara)*, insects and small birds (Hagen, 1952; Fargallo et al., 2003). Old crow nests (*Corvus corone cornix*), cliffs and cavities in trees are the most frequent nesting sites for kestrels in Norway (Hagen, 1952; Tømmeraas, 1994), but they can also use ledges on buildings, stick-nests of other bird species (Village, 1990) and nest boxes (Cramp and Simmons, 1980). Like the other falcons, they never build their own nests (Village, 1990). The kestrel is sexually mature and can breed at one year age, and the eggs are usually laid in late May or early June (Tømmeraas, 1994). Clutch sizes varies from 1-9, but 3-6 is most common (Cramp and Simmons, 1980). The incubation time is 27-29 days per egg and the whole brood is hatched within 3-5 days. The fledging period is 27-32 days. During the 14 first days after hatching the male provides food to the female who divide the prey among the nestlings. The rest of the period both parents bring prey items to the nest and the nestlings eat by themselves (Cramp and Simmons, 1980; Fargallo et al., 2003). One month after leaving the nest the young kestrels are independent (Cramp and Simmons, 1980; Peterson, 2001).

In this study I used radio-telemetry to study home range size, different aspects of behaviour and habitat use of three male Eurasian kestrels during the breeding season in 2008.

METHODS

Study area and species

This study was conducted in Trysil municipality in Hedmark county, south eastern Norway (61º 07′ - 61º 28′ N; 12º 06′ - 12º 43′ E) at altitudes of 600-800 meters in June – July 2008. The study area is situated in the mid and north boreal vegetation zones, and has a continental climate and a duration of snow cover ranging between 150 and 200 days (Moen, 1998). The study area covers about 50 km^2 and the habitat is dominated by coniferous forest of different age, including clear cuts and large areas with bogs. One of the home ranges also included small patches of farmland (pasture), but overall farmland covers a negligible part of the study area. The kestrel locations are hereafter referred to as Orrleikåsen, Granåsen and Svarttjønnen, and associated nests were in nestboxes on a young clear cut, an old clear cut, and a bog, respectively.

Capturing and radio-tagging the kestrels

The nest boxes were checked several times to determine date of hatching. All young were older than two weeks before the capturing of the males. At this age the nestlings are able to thermoregulate by themselves (Village, 1990) and the parents will return to feed them almost immediately after the disturbance (Steen, 2009). The nest boxes where the kestrels were captured were among 10 nest boxes used in another study for monitoring prey deliveries, in which the original nest boxes were replaced with new boxes designed to accommodate video monitoring as described by Steen (2009).

Attempts to capture kestrel males were made at nine nests, but were successful only at three. The males were trapped inside the nest box when they entered to deliver prey to the nestlings. At the first location, Orrleikåsen, we first captured the female by using a swing-door that was mounted in the entrance of the nest box. The swing-door was held up by a stick in which I had tied a 25 m long thin wire. I was sitting in a hide about 20 m from the nest box. As soon as the female entered the nest box I pulled the wire, closing the swing-door. The door was then held closed by two magnets. Then we mounted a new box outside the first one with a new swing-door with the same design as the one on the nest box. The female was now inside the nest box along with the nestlings. We provided them with 3-4 small rodents while we waited for the male to enter the trap. There was only a thin net between the nest box and the other box so that the male could see the female inside. When the male was captured we demounted the trap-box with the male kestrel in it. At the remaining nest boxes we improved the capturing method. By studying prey deliveries from the video, I was able to select for capture only those nest boxes where the male was delivering prey directly to the nestlings. Further, I had a portable LCD TV inside the camouflage, as described by Steen (2009), which enabled me to see inside the nest box to decide the sex of the arriving kestrel. I also used binoculars to determine the sex of the arriving bird. As soon as the male entered the nest box I pulled the wire, closing the swing door. The door was held closed by to magnets until we could climb up to remove the kestrel and the swing-door.

The kestrels were fitted with a radio transmitter (Biotrack, UK) fastened to the central tail feathers as described by Kenward (1978) (Figure 1). This has the benefit that the transmitter would fall off by itself when the kestrel moulted, in contrast to transmitters mounted as back packs. For birds, one should always take into concern the mass ratio between the transmitter and its carrier (White and Garrott, 1990). The transmitter mass in my study was only 5 g. If we assume that mean weight for the male kestrels is c. 200 g (Village, 1990), the transmitter amounted to only 2.5 % of the carrier’s mass. This is far below the upper limit of acceptance which is c. 5 % (White and Garrott, 1990). As judged from the plumage the male at Orrleikåsen was one year old and the males at Granåsen and Svarttjønnen were both at least two years old according to Village (1990). Two of the kestrels were allowed to habituate to the transmitter until the following day before being tracked for data collection, while the male at Orrleikåsen was followed and located the same afternoon as we captured him. He was then hunting seemingly normal. For the whole study I assume that the radio-tagged kestrels acted similar to untagged individuals.

Figure 1. The kestrel male at Svarttjønnen just before being released after being equipped with radio transmitter (Photo: Øivind Løken).

There are few studies showing negative effects of radio transmitters on birds (Iverson et al., 2006; Steenhof et al., 2006; Scmidt-Wellenburg et al., 2008) and even fewer on kestrels (Village, 1990). But given the low ratio between the transmitter mass and the kestrel's body mass, and the fact that all the nestlings of the three studied males survived the study period, I regard the effect of radio transmitters on the kestrels to be insignificant.

Radio-tracking

I used a 6-element handheld yagi antenna (Televilt, Sweden) and a RX-81 receiver (Televilt, Sweden) to track the kestrels. When possible, roads were used to find the approximate position of a kestrel, but tracking by foot was always used to obtain a more exact position. Tracking was done by homing in (White and Garrott, 1990) on the kestrel and active use of binoculars until I located the kestrel by eyesight or realized from vaning radio signals that I had frightened it. The location where the kestrel was seen (or a minimum outer range point when I frightened it without spotting it) was recorded on a Garmin GPS (Global Positioning System) Map® CSx (Garmin, USA) receiver. Additional variables recorded at each location in the field were date, time, temperature (ºC), wind (no wind, moderate wind or strong wind), cloud cover (cloudless, partly clouded or cloudy), precipitation (yes or no), behaviour (perching, hovering or flying), perching post (pine (*Pinus sylvestris*), spruce (*Picea abies*) or birch (*Betula pubescens*)), perch height (m), fright distance (m), forest type, dominant tree (pine, spruce or birch), forest height (m), forest age (classes 1-5), forest structure (open, medium or dense), distance to open habitat (m) and distance to closed habitat (m). Fright distance was taken as the distance from the observer to the kestrel as it left the perch as a reaction to the approaching observer. Since I did not know how much information the digital maps contained when I collected data in the field, forest type was described at the site and later transformed to the habitat types in the digital map.

To avoid autocorrelation of the locations, I attempted to locate the radio-tagged male kestrels at different times from day to day during the study period. However, I did not employ a lower time limit between locations in each home range. The level of autocorrelation may vary during the day and between days (Rooney et al., 1998) and there could be many aspects to take into concern trying to obtain as independent observations as possible. White and Garrott (1990) give a general thumb rule to decide whether two locations are statistically independent or not, namely whether enough time have elapsed for the animal to move from one end of the home range to the other. If using this rule autocorrelation is negligible in my study. I obtained a total of 130 locations on the three male kestrels.

GIS

The GPS-locations collected in the field were downloaded to a computer and marked on a digital map (Skog og landskap, 2009). Home range-calculations and extracting of data for the habitat analysis were done in ArcView® Gis 9.3 (ESRI, 2009). ArcView® Gis 3.2 (ESRI, 1996) was used to remove 5 % outliers before making the 95 % MCPs. I estimated home range with the Minimum Convex Polygon (MCP) method (Andreassen et al., 1993; Huck et al., 2008), and both 95 % and 100 % MCPs were calculated to see possible effects of outliers. At each kestrel location in the field the habitat was registered. Due to different observers and the fact that some GPS plots were taken without observing the kestrel, the habitat was only registered at 87 of the 130 locations. In each home range I generated 100 random points and intersected these points with the digital map to get information of the habitat type at each plot. Dussault et al. (2001) questioned both the accuracy of the GPS-plots and the habitat classifications in the digital maps, especially at the edges of different habitat types. To try to avoid this I made buffers with 25 m radius around both the random points and the observed locations. The choice of a buffer radius of 25 m was based on experiences from a similar study on the Ural owl (*Strix uralensis*) (Braathen, 2009). The buffer area was also filled with habitat information from the digital map. Habitat information from the digital map was coded ATIL (Bjørdal et al., 2004) which is short for area state in Norwegian. The habitat types I used were (ATIL codes in paranthesis): water/road (1), bog (11), bog with forest (12, 13, 14), farmland/pasture (21, 22, 23, 27), coniferous forest (24), mixed forest (25) and deciduous forest (26).

Snap trapping

Snap trapping of small mammals was performed separately at each of the three localities. The area surrounding each nest was set with 120 traps for two consecutive days and nights, yielding 240 trap nights per nest. The nest was chosen as origin and 30 traps were put out at intervals of 10 m in each of four directions (N, E, S, and W). The traps were checked after the first night and collected after the second. For each trap released due to other disturbance than a small mammal, 0.5 trap nights were subtracted. For each locality a trapping index was calculated for each small mammal species or genus as number of individuals captured per 100 trap nights.

Statistics

Statistics and figures were calculated in JMP® 4.0 (SAS, 2000) and tables and figures were made in Excel® (Microsoft, 2000). Differences between used and available habitat were tested by nominal logistic regression both for point locations and buffers. The variables which were significantly different between the observed and random plots were tested separately to see if they still differed significantly. Whether there were any differences between used and available forest age class was tested by a contingency analysis. I obtained information on forest age distribution in the study area from Trysil Kommuneskoger (Foran, 2007). Stepwise regression with backward elimination was used to test variables affecting fright distance and perch height. Variables were chosen based on AIC values and were considered to have a significant effect if Δ AIC > 2. The residuals in the final model were tested for normality. Logistic regression was used to test variables affecting whether the kestrel was hovering or not. A proxy for solar height was taken as the number of minutes from solar midnight. I assumed that it was darkest at 01.00 (midnight local summer time) and most light at 13.00, meaning that an observation at midnight would get the value 0 and an observation at 13.00 the maximum value of 720.

RESULTS

Home range: Size in relation to number of locations

The kestrel males were located from 32 to 52 (mean 43.3 ± 10.3, n = 3) times. The larger number of locations at Granåsen and Orrleikåsen is due to a larger effort on these locations by several observers. The transmitters on the Granåsen and Svarttjønnen males sent signals for exactly three weeks (21 days), while the signal at Orrleikåsen was lost 4 days earlier, resulting in locations from fewer days (Table 1).

Table 1. *Number of plots, number of days tracked and estimated home range sizes (km^2), both for100 % and 95 % MCP (Minimum Convex Polygon) for the three male kestrels tracked.*

Location	Plots	Days tracked	100 % MCP	95 % MCP
Orrleikåsen	52	13	2.23	1.90
Svarttjønnen	32	18	0.81	0.71
Granåsen	46	18	3.55	3.01

The overall home range sizes for the tree males leveled off and stabilized at three different levels. At all locations the ten last locations did not increase the home range size (Figure 2).

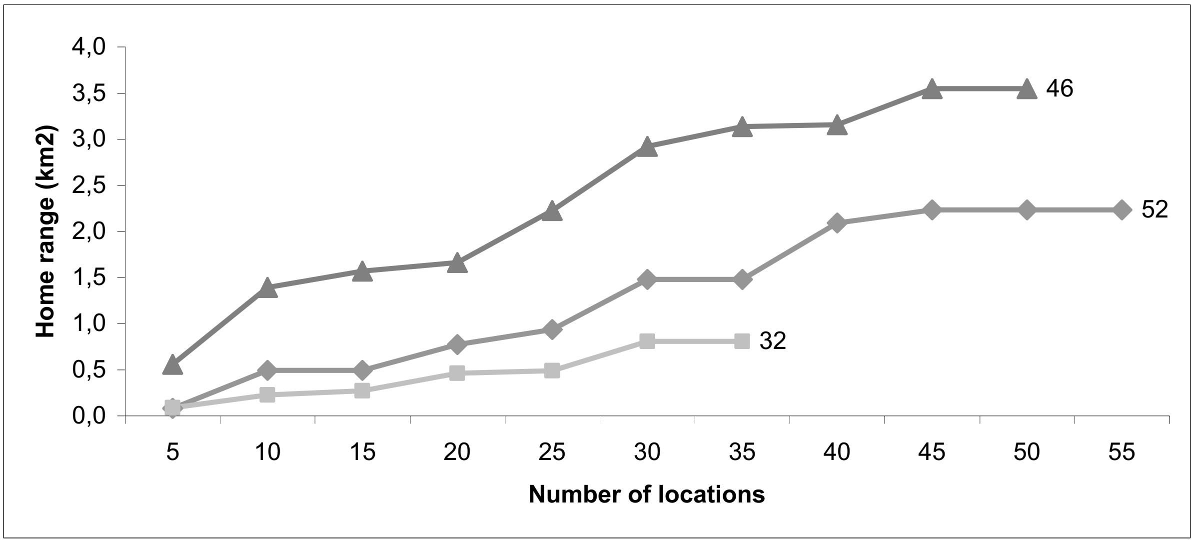

Figure 2. *Estimated 100% MCP home range size for the male kestrels at Svarttjønnen (bottom line), Orrleikåsen (middle line) and Granåsen (upper line) as a function of number of locations. The number at the end of each line is the total number of locations for each male.*

Home range: 100 % MCP and 95 % MCP

Home range size varied a great deal between the individuals and ranged from 0.81 km^2 to 3.55 km^2 for 100 % MCP and 0.71 km^2 to 3.01 km^2 for 95 % MCP (Table 1 and Figure 3).

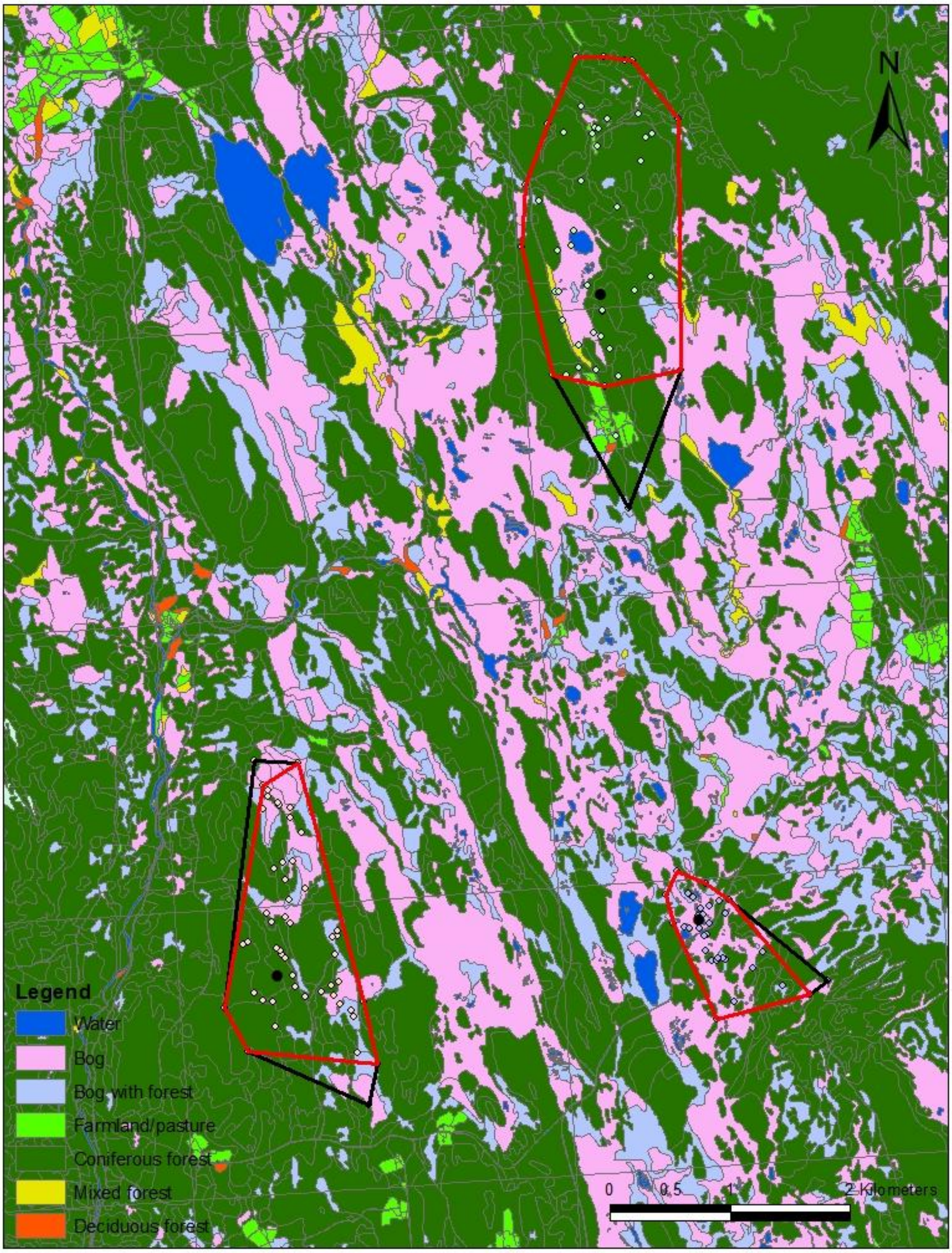

Figure 3. *Home range for the three male kestrels tracked. Black polygons indicate 100 % MCP and red polygons indicate 95 % MCP. The nest is shown by a black dot and the other dots within the polygons are the locations of the kestrels.*

Home range: Size in relation to territory quality

The most important small mammal prey group for kestrels is *Microtus* voles (Village, 1990). Therefore, I regard the trapping index of *Microtus* voles in my study (field voles (*Microtus agrestis*) and tundra voles (*Microtus oeconomus*) pooled) to reflect the territory quality. Then Granåsen would be ranked as having the lowest quality, Orrleikåsen as having medium quality, and Svarttjønnen as having the highest quality (Table 2). These results are reflecting the home range sizes; the male at Granåsen having the largest home range, the male at Orrleikåsen having the medium home range, and the male at Svarttjønnen having the smallest home range.

Table 2. *Trapping index from snap trapping at each of the three localities; Granåsen, Orrleikåsen and Svarttjønnen.*

Locality	Trap nights	Trapping index (animals per 100 trap nights)				
		Bank vole	*Microtus* voles	Wood lemming	Common shrew	Total
Granåsen	236	1.3	0.4	1.7	0.4	3.8
Orrleikåsen	239	1.3	2.1	0.4	0.8	4.6
Svarttjønnen	223	3.6	3.6	4.9	0.5	12.6

Habitat: Area categories

There were very few locations, both random and observed, scored as water/road, farmland/pasture, mixed forest and deciduous forest (Figure 4), so these habitat types were excluded from the analysis. The probability that a location was an observation of a kestrel rather than random was significantly affected by all the remaining three habitat types; bog, bog with forest and coniferous forest (Table 3). However, the logistic regression model used in this analysis was found to be overdispersed. This should be kept in mind when interpreting these results, because it may make the findings more uncertain.

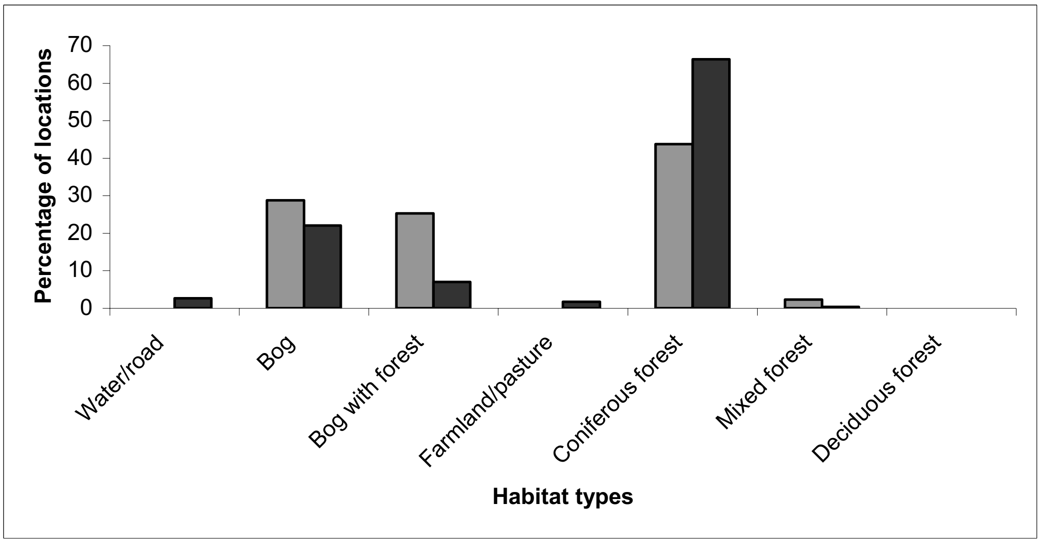

Figure 4. *The distribution of recorded locations of three kestrel males (grey bars) (n = 87) and random locations (black bars) (n = 300) in each habitat type. The category of the observed locations is registered by me in the field while the random locations are projected in ArcMap (Esri, 2009). There are 100 random points in each home range.*

Table 3. *Nominal logistic regression model of variables significantly affecting the probability that male kestrels used habitats different than randomly expected, based on analyses of the observed use of habitat types compared to availability in point locations. Whole model: n = 430, df = 5,* $X^2 = 88.32$*,* $R^2 = 0.17$ *and* $p < 0.0001$*.*

		Whole model		Parameter estimate			
Variable	df	X^2	P	Estimate	SE	X^2	P
Intercept				-1.98	0.29	45.71	<0.0001
Bog	1	26.26	<0.0001	1.00	0.21	23.55	<0.0001
Bog with forest	1	5.42	0.0199	0.51	0.22	5.28	0.0216
Coniferous forest	1	74.99	<0.0001	1.40	0.18	61.45	<0.0001

When the variables were tested separately, only coniferous forest and bog with forest significantly differed between the observed and random plots (Figures 5 and 6).

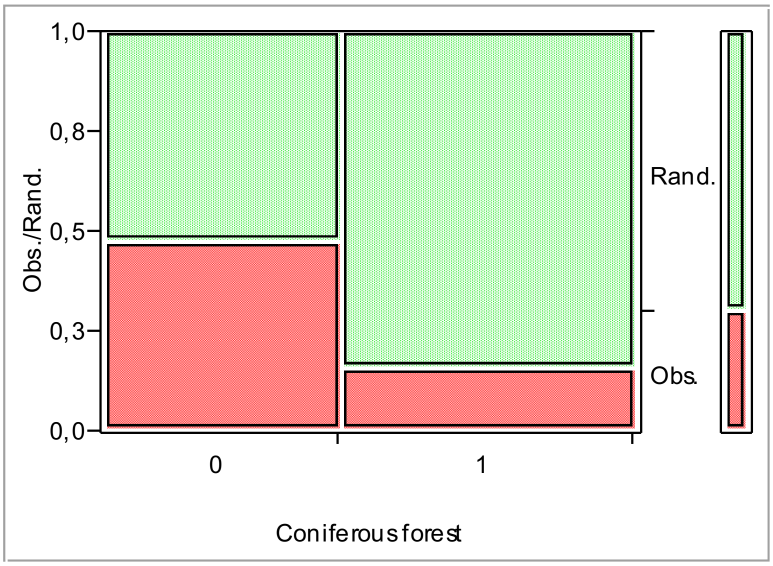

Figure 5. *The probability that a location was either an observation or random of a male kestrel when located in coniferous forest (1) or not located in coniferous forest (0) (n = 430, df = 1,* x^2 *= 51.22, p < 0.0001).*

Figure 6. *The probability that a location was either an observation or random of a male kestrel when located in bog with forest (1) or not located in bog with forest (0) (n = 430, df = 1,* x^2 *= 9.18, p = 0.0025).*

When I used the habitat composition in a buffer of 25 m radius around each location rather than the habitat in the point of location the probability that a location was an observation of a kestrel rather than random was significantly affected by bog, bog with forest and by kestrel identity. The effect of the kestrels at Granåsen and Orrleikåsen differed significantly from each other (Table 4).

Table 4. *Nominal logistic regression model of variables significantly affecting the probability that male kestrels used habitats different than randomly expected, based on analyses of the observed use of habitat types compared to availability in buffers of 25 m radius around each location. Whole model: n = 429, df = 4,* $X^2 = 15.12$, $R^2 = 0.029$ *and* $p = 0.0045$.

		Whole model		Parameter estimate			
Variable	df	X^2	P	Estimate	SE	X^2	P
Intercept				-1.65	0.27	38.2	<.0001
ID (random)	2	7.59	0.023				
ID (Granåsen)				0.76	0.30	6.25	0.012
ID (Orrleikåsen)				0.64	0.28	5.17	0.023
Bog	1	8.07	0.0045	0.00046	0.00016	8.10	0.0044
Bog with forest	1	6.15	0.013	0.00061	0.00024	6.31	0.012

When these variables were tested separately, none of them had a significant effect on the probability that a location was used by a kestrel rather than randomly selected, although bog and bog with forest would both have been significant with a level of significance at 0.10 (Figures 7 and 8).

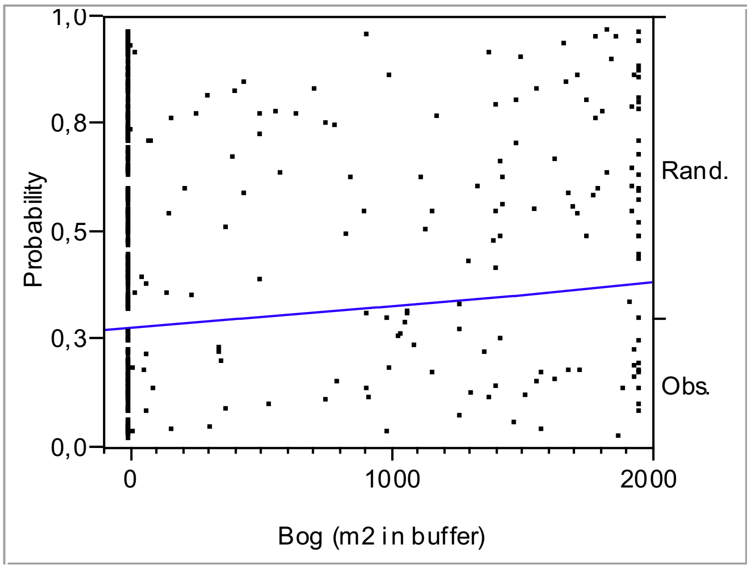

Figure 7. *The probability that a location had been used by a male kestrel rather than being randomly selected within the kestrels home range, as a function of coverage of bog in the buffer around the location (n = 429, df = 1,* $x^2 = 2.69$, $R^2 = 0.0051$, $p = 0.10$*). The curve describes the logistic regression model. The dots are residuals and not observed values.*

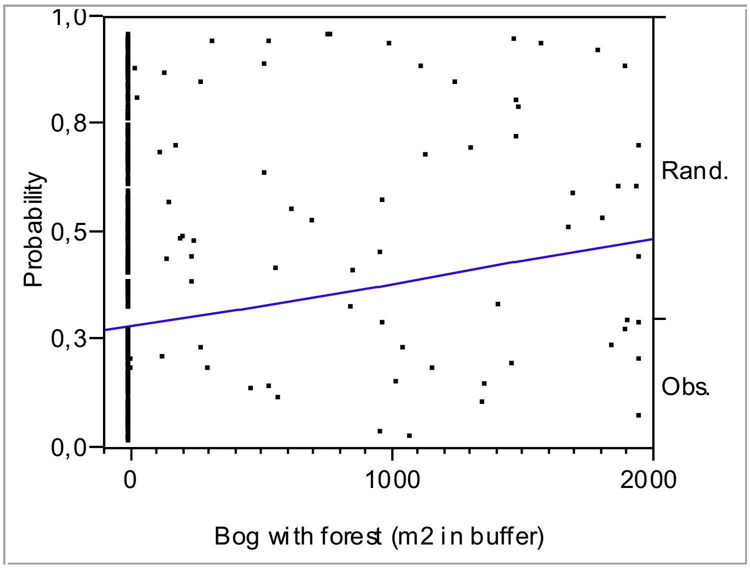

Figure 8. *The probability that a location had been used by a male kestrel rather than being randomly selected within the kestrels home range, as a function of coverage of bog with forest in the buffer around the location (n = 430, df = 1,* $x^2 = 3.66$, $R^2 = 0.0069$, $p = 0.056$*). The curve describes the logistic regression model. The dots are residuals and not observed values.*

Habitat: Forest age

There was no significant difference between the kestrels in how old forest they used (Figure 9). However, the distribution of forest age based on all observed kestrel observations differed significantly from expected observations based on the estimated age distribution of the forest (Figure 10). The most apparent deviations were more use of clear cuts and less use of old forest compared to randomly expected. The kestrels seemed to prefer clear cuts (forest age class 1) and avoid old forest (forest age class 5) (Figure 10).

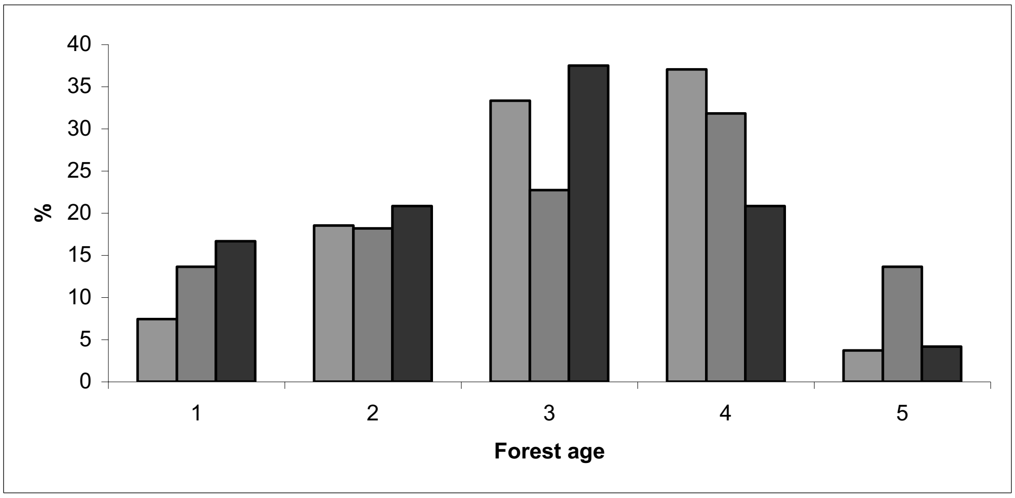

Figure 9. *Distribution of locations of three male kestrels on five age classes of managed coniferous forest, where 1-5 denotes the successional stages from clear cut (1) to mature forest (5).Granåsen = light grey bars, Orrleikåsen = dark grey bars and Svarttjønnen = black bars (n = 73, df = 8,* $X^2 = 5.01$, $p = 0.76$*).*

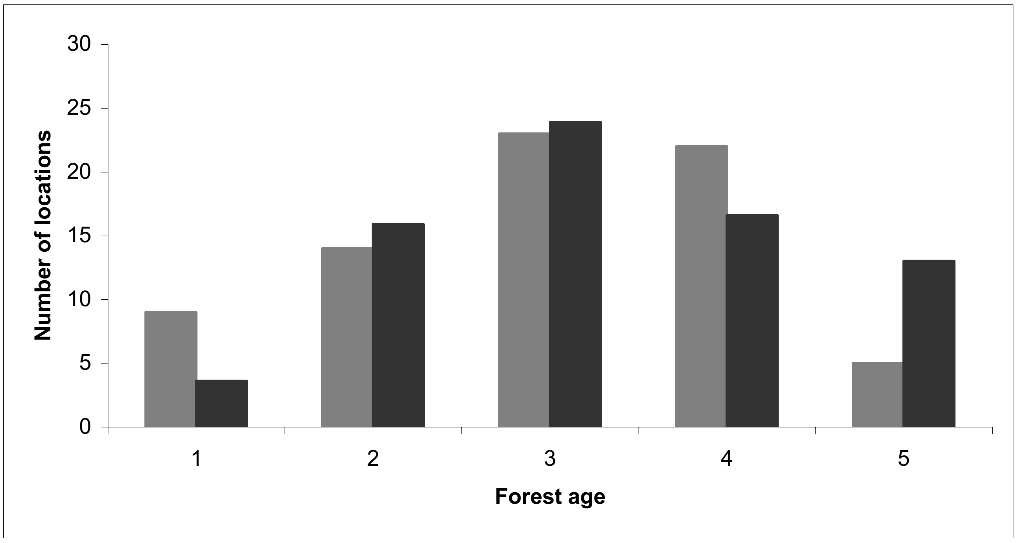

Figure 10.. *Distribution of observed locations of three male kestrels and expected observations on five age classes of managed coniferous forest, where 1-5 denotes the successional stages from clear cut (1) to mature forest (5). Observed = light grey bars, expected = black bars (n = 73, df = 4,* $X^2 = 15.04$ *, p < 0.01).*

Behaviour: Fright distance

Mean fright distance was 74.7 ± 7.4 m (n = 52). The reason why the fright distance was not registered at some of the locations was either that the kestrel was not observed when frightened, or that the kestrel was considered unaffected by the observer. The fright distance increased with increasing proportion of bog in the home range and with increasing distance to the nest (Table 5). Both variables also explained the fright distance separately (Figures 11 and 12). None of the other variables tested could explain the fright distance. These variables were amount of light (time of day), temperature, wind, cloud cover, precipitation, perch height, other habitat types than bog, forest height, forest age, forest structure, and distance to open and closed habitats.

Table 5. *Stepwise regression model of variables significantly affecting fright distance of the three kestrels. Cumulative values are given for* R^2 *and AIC. The other values are from the whole model (n = 51). Variables chosen after a backward elimination.*

Variable	df	Regression coefficient	SE	R^2	P	AIC
Intercept		25.55	11.51			408.10
Distance to nest	1	0.053	0.012	0.25	<0.0001	395.25
Bog	1	0.022	0.0083	0.35	0.011	390.33

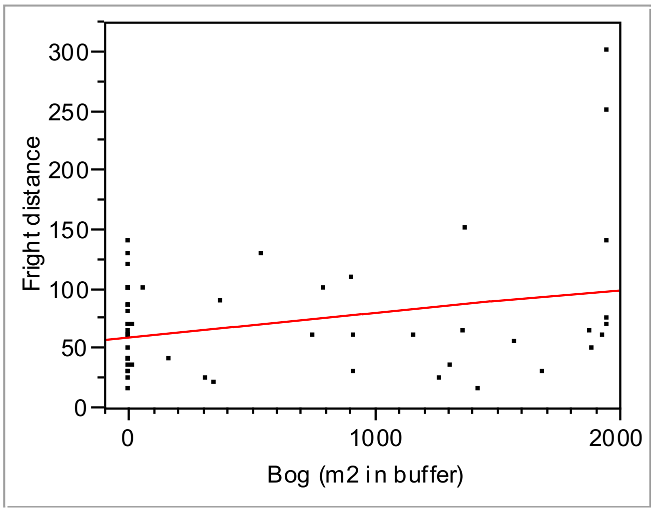

Figure 11. *Fright distance of three male kestrels in relation to the coverage of bog in the buffer around the observed plots (n = 51, df = 1,* R^2 *= 0.06, F = 4.09, p = 0.049. Y = 0.0197x + 61.5).*

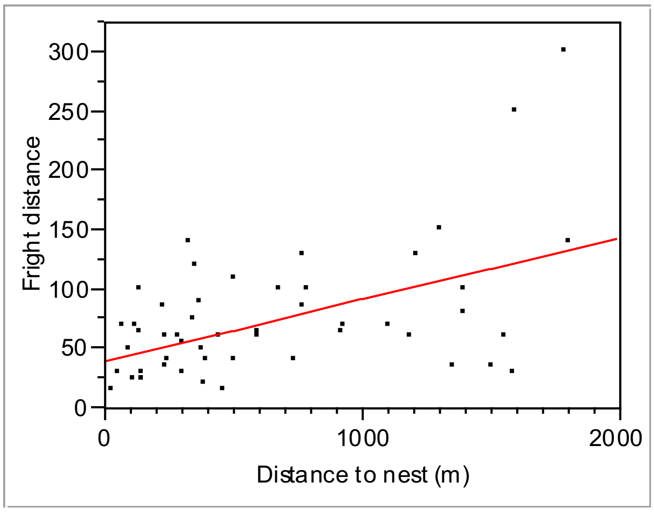

Figure 12. *Fright distance of three male kestrels in relation to the distance from the nest to where they were located (n = 51, df = 1,* R^2 *= 0.25, F = 16.56, p = 0.0002. Y = 0.051x + 40.85).*

Behaviour: Perch

The kestrels used the most abundant tree in the vicinity as perch tree (Figure 13). Mean perch height was 17.5 ± 1.3 m (n = 62). I found no significant effect on perch height of any of the variables tested, which were solar height (time of day), temperature, wind, cloud cover, precipitation, habitat type, forest height, forest age, forest structure, distance to open and closed habitats, and distance to nest.

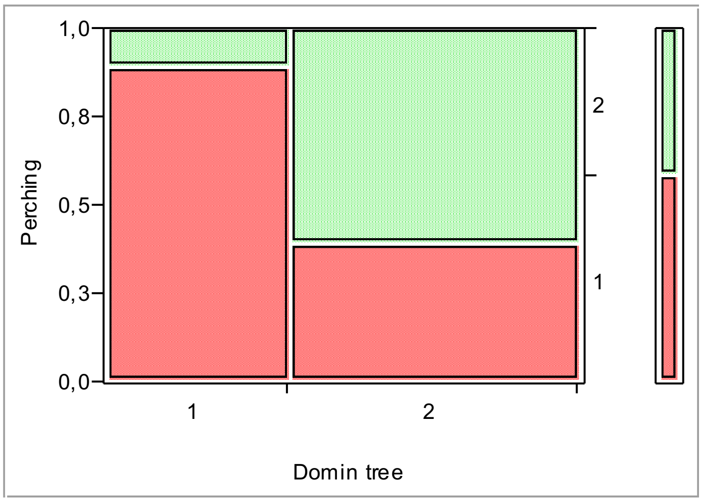

Figure 13. *Perch tree of located kestrels (n = 3) in relation to the dominating tree species in the surroundings of the location (n = 46, df = 1,* x^2 *= 12.29,* R^2 *= 0.197, p = 0.0005). 1 = Pine, 2 = Spruce.*

Behaviour: Perching or hovering

The variables tested here were solar height (time of day), temperature, wind, cloud cover, precipitation, perch height, habitat type, forest height, forest age, structure, distance to open and closed habitats and distance to nest. The only variable that could explain whether a kestrel was perching or hovering was solar height. The higher the sun, the more likely that the kestrel was hovering (Figure 14). There were no effect of locality (kestrel ID).

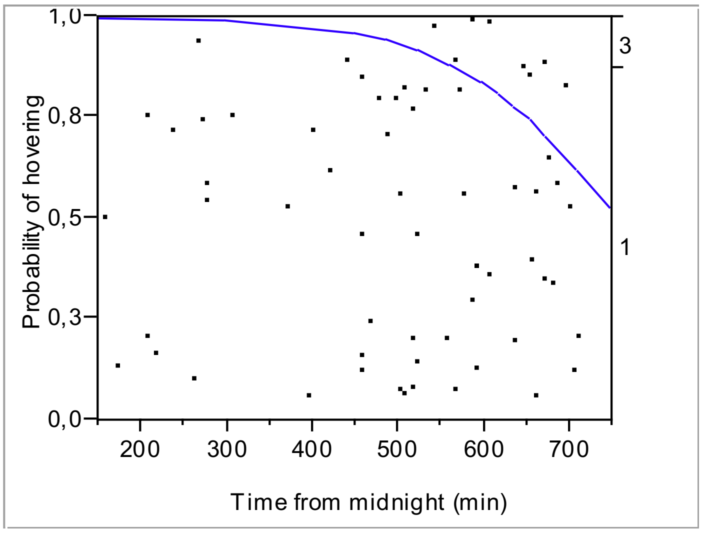

Figure 14. The probability that a kestrel was hovering or perching as a function of solar height (n = 64, df = 1, x^2 = 7.75, R^2 = 0.16, p = 0.0054). The curve describes the logistic regression model. 1 = perching, 3 = hovering. The values on the x-axis are minutes between 01.00 and 13.00, indicating the solar height during the day. The dots are residuals and not observed values.

DISCUSSION

Home range

I used both 100 % and 95 % minimum convex polygons (MCP) to estimate home range sizes for the three male kestrels studied. 95 % MCP was used in addition to the 100 % MCP to investigate possible effects of outliers. The 95 % MCP was of course smaller than the 100 % MCP, but not so much smaller that I could claim any outlier to have a considerable effect on the 100 % MCP home range estimates. To my knowledge there is only one previous study using radio telemetry to investigate home range size in kestrels. In this study Village (1982a) used the MCP home range estimator to calculate home range size, and one of the main reasons for me to apply the same method was the opportunity to compare. Mean uncorrected and corrected home range size in the study (Village, 1982a) was 2.08 and 4.08 km^2, respectively. This is quite similar to my estimates, except for that of the male kestrel at Svarttjønnen, which amounted to only 0.81 km^2 (100 % MCP). Village (1982a) found that home range size was strongly dependent on sample size in ranges with less than twenty locations, and therefore needed to correct some home range estimates (see Village, 1982a for the correction procedure). Village (1982a) also showed that the increase in home range size per location levelled off after 20 locations, which supported that these ranges approached the final range size. The fact that all home range estimates in my study were based on more than 32 locations, and that there was a clear tendency for a slowing in the rate of range size increase in all home ranges, indicated that my estimates approached the final range sizes.

Marzluff et al. (1994) noted that falcon foraging ranges, especially those for breeding males, were often underestimated, because the falcons spent a majority of their time near their nests and were therefore often located close to the nest sites. Although their study dealth with Praire falcons (*Falco mexicanus*) I noted the same tendency in my study. Since the male kestrels used markedly more time near the nests than farther away, the probability of finding a kestrel near the nest site on a randomly chosen time is larger than finding it farther away. This may have led to an underestimation of the home ranges. I believe though, that this effect decreases as the number of locations per home range increases.

Worton (1987) mentioned the possibility of an animal changing home range in the course of the study period. This may have been the fact for the male kestrel at Orrleikåsen, since I lost the radio signal here earlier than at the other two localities. However, I find it more likely that loosing the signal was due to malfunction of the radio transmitter. I observed a male kestrel near this nest after loosing radio contact, and although I can not be sure this was in fact the same male, I find it most likely that the kestrel was still in the home range after I lost radio contact with him. All the young fledged after loss of radio signals, and this fact suggests that he was still in the area, supplying the young with food. Nevertheless, I can not disregard the possibility of an increase in home range size at Orrleikåsen if I had the same number of tracking days there as at the other two localities, but I do believe it would have only lead to minor changes, due to the high number of previous locations at Orrleikåsen.

I found that the kestrels' home range size was inversely related to territory quality, when I regarded the trapping index of *Microtus* voles to reflect the territory quality. Village (1982a) also found that home range size in kestrels were closely related to vole abundance, and that in general, ranges were smaller when voles were abundant than when they were scarce. This is expected from the optimal foraging theory (Krebs, 2001); predators will minimize energy costs and maximize fitness and choose habitat thereafter. The vole numbers at high latitudes in the northern hemisphere fluctuate in 3-4 year cycles (Henttonen et al., 1989), and many studies show interactions between vole numbers and their predators (e.g. Hagen, 1952; Cramp and Simmons, 1980; Village, 1982a). Temeles (1987) found that mice was the main prey of harriers (*Circus cyaneus*), and even though the harriers could take alternative prey, the best mice habitat was defended against other harriers and was the most important factor in determining territory size. However, it is not necessarily the habitats with the highest vole density that in the long term provide the best home range locations for kestrels, since the kestrels may feed largely on alternative prey (Tømmerås, 1994; Valkama et al., 1995). Kestrels do not specialise on a specific prey type, rather on a specific hunting method. Hence, the number of alternative prey, i.e. other prey than voles, in the diet reflects the abundance and availability of alternative prey in their home range (Village, 1982b). The fact that raptors capture the prey which is most available and has the smallest energetic costs is also shown in Northern goshawks (*Accipiter gentilis*) (Tornberg et al., 2009).

Even though the kestrel is a generalist predator, voles are the major food source and have undoubtedly an effect on the kestrels' choice of habitat and home range size (Village, 1982a; Masman et al., 1988). The importance of voles for the kestrel is also supported by the fact that they have to hunt more in low vole years (Riegert et al., 2007) and their ability to spot scent marks from voles and even decide the species and the reproductive category (Viitala et al., 1995; Koivula et al., 1999). In this way kestrels may be able to screen large areas for good vole habitats and even determine which stage of the vole cycle (Koivula et al., 1999). The evolving of such a skill in my opinion proves that voles and their abundance are of great importance for choice of home range and home range size in kestrels.

Myers et al. (1979) proposed two hypotheses for how territory size is determined. First, an animal assesses prey density and directly adjusts territory size to include resources sufficient for its own energetic needs and for bringing up the young. Second, an animal defends an area as large as it can, but territory size is constrained by competition. Although some studies to some extent mixes the terms territory and home range (Schoener, 1968), I think it is important to separate between the two by using the definitions mentioned above (Burt, 1943; Mohr, 1947). This idea was supported by Village (1983b), who showed that both home range size and territory size in kestrels varied between years depending on food supply. Village (1983b) also showed that kestrels defended parts of their range around the nest, and that overlap of male ranges increased with increasing distance from the nest. In line with this, I observed another kestrel male hunting in the outermost part of the home range at Granåsen (pers. obs.). Nevertheless, the first hypothesis of Myers et al. (1979) seems to be quite suitable also for home range size in my study.

Habitat

I found differences between used and available habitat for the habitat types bog, bog with forest and coniferous forest based on the point locations and for bog and bog with forest when I analyzed the habitat composition in the buffers. Also available and used forest age classes differed. In particular, clear cuts (forest age class 1) were more used than one would expect from a random distribution.

Although I find it hard to draw clear conclusions from my results on habitat use, they point in the same directions as many other studies. The analysis based on the point locations were highly significant, but could have been affected by overdispersion, and this has to be kept in mind. However, since the same pattern was found in the analyses based on habitat composition in the buffers, the preference for bog and bog with forest seems clear. Also, the result showing extensive use of clear cuts I find very reliable. My personal observations also supports the tendency of the kestrels to prefer both habitat types bog and bog with forest. Dussault et al. (2001) suggested that the accuracy in the digital maps as well as in GPS-locations could be possible sources of error. Differences in the way habitat information was sampled in my study and in the digital maps may also make my findings less accurate (Aarts et al., 2008). The accuracy of GPS receivers has improved a lot the last few years, so I do not regard this as an important source of error. Problems connected to use of habitat edges are more plausible to have affected my results. The kestrels were often perching in edges between for instance a bog and older coniferous forest, or between a clear cut and older coniferous forest. In most of these cases the habitat was classified as old coniferous forest, because the kestrel was perching in this habitat, while it was the bog, or the clear cut, which was the reason of the kestrel being there. Hopefully, I avoided this problem by using the buffer zones, but in the analysis of the point locations this problem may have lead to misleading results.

Kestrels depend on open area to hunt, but apart from this they can use a wide range of habitats (Village, 1990; Tapia et al., 2008). Modern forestry have had different impacts on different raptor species (Niemi and Hanowski, 1997). While for instance goshawk populations have declined due to modern forestry (Widèn, 1997), the kestrel is likely to profit from modern forestry by making use of clear cuts (Village, 1982b; Sonerud, 1986, 1997). Village (1982b) showed that voles increased more than other prey in an area after clear cutting, and that voles were even more abundant on clear cuts than on farmland. However, the availability of prey in clear cuts varies a lot throughout the season. It increases during the snow melt with a peak in June when the vegetation starts growing, and then decreases during summer as the vegetation layer in the clear cuts gets more dense, making it harder for the kestrels to detect their prey (Sonerud, 1986, 1997). According to these findings I believe I would have seen an even more extensive use of clear cuts if the male kestrels had been tracked earlier in the summer. Clear cuts could also be a suitable nesting habitat since the kestrels' preference for a particular nest site increases with increasing distance to forest edges (Valkama and Korpimäki, 1999). Many of the artificial nest boxes in my study area in Trysil were in fact placed in clear cuts (pers. obs.). Another aspect of modern forestry is thinning and selection felling. This had been done in a forest stand in the Granåsen home range (pers. obs.). Apparently, this opened the habitat enough for the kestrel being able to hunt there, and-, on several occasions I actually observed him hunting there, hovering high above the tree tops. I have not been able to find other studies showing that kestrels hunt in selection felling forest areas.

The home range at Granåsen also included small areas of farmland. I had expected to find the kestrel hunting in these more often, but this was not the case. Aschwanden et al. (2005)

showed that farmland was attractive hunting sites for kestrels in periods, depending on the vegetation height. Aschwanden et al. (2005) also stated that even though the vegetation in farmland was too high or dense for the kestrel to spot their prey, farmland could function as refuges for small mammals and therefore be of importance for the prey density in the adjacent areas. Some of the farmland at Granåsen was heavily grazed by cattle, which would have made it easy for the kestrel to detect both voles, insects or other prey there, but they seemed to prefer hunting in other habitats.

Behaviour

I found that fright distance increased with increasing proportion of bog in the home range and with increasing distance to the nest. For perch height I found no effect of any of the variables tested, although my observations of the kestrels in the field gave me the impression that they preferred the highest available perch. The kestrels did not have any particular preferences concerning perch trees; they used the most available tree. Solar height was the only variable significantly explaining whether a kestrel was hovering or perching.

In my opinion it is quite logic that the amount of bog explained fright distance. Kestrels hunt by vision (Village, 1990) and has an excellent eyesight. They would therefore detect me much earlier in an open bog than in more dense habitats. I have not been able to find studies describing kestrel fright distance when approached by humans, but my observations in the field showed that the kestrels for sure was frightened by me and left their current position when approached. Village (1990) claimed that kestrels use alarm calls when disturbed by humans near the nest. This was especially noticeable in the Svarttjønnen home range, and is probably a behaviour for protecting the nestlings. The aggression towards other kestrels is also stronger the closer to the nest the encounter happens (Wiklund and Village, 1992). Hakkarainen and Korpimäki (1994) showed that male nest defence in Tengmalm's owls (*Aegolius funereus*) was related to the survival prospects of the offspring. This could also be the case in kestrels. In my study area in Trysil the aggression levels and nest defence behaviour has been observed to vary between years (G. A. Sonerud and R. Steen, pers. com.), with seemingly more aggressive behaviour in good vole years. This suggests that the kestrel uses the same strategy as shown for Tengmalm's owls (Hakkarainen and Korpimäki, 1994). Male kestrels being more aggressive close to the nest, would also explain the relation between fright distance and distance to the nest, which agrees with my results.

I would have expected perch height to be related to forest height, but I found no relationship between these variables. A possible explanation may be that even though the forest height was quite similar throughout a forest stand, the kestrel seemed to choose the highest possible perch within it, and the height of this perch was not necessarily related to the rest of the forest stand. For instance, the perch tree could be a very old and tall spruce in a younger spruce stand, or it could be the highest tree in a quite uniform forest stand. Trees are important for kestrels to hunt from, and the importance of suitable perch trees was shown in a study on the Mauritian kestrel (*Falco punctatus*) (Burgess et al., 2009). Farmland was expected to be very good hunting habitats for the Mauritian kestrel, but the kestrels used this habitat less than expected (Burgess et al., 2009). This was assumed to be due to lack of suitable perch trees, and this was supported by the fact that in farmland with some isolated large trees, the Mauritian kestrels used these trees as perches (Burgess et al., 2009). In my study area there were no open areas large enough to make lack of perch trees a problem, and the kestrels chose to perch in the most abundant tree.

The kestrel most usually hunts either from perches or from the air (Village, 1990). Flight hunting is the most effective hunting technique (Rijnsdorp et al., 1981; Masman et al., 1988), but also the most energy demanding one (Masman et al., 1988; Riegert et al., 2007). Flight hunting includes both directional flight and wind hovering, but the energy expenditure in the two are approximately the same (Masman and Klaassen, 1987). Whether the kestrel hunts from the air or from perches may vary within the season or by time of the day (Village, 1983a; Masman et al., 1988) and may also be affected by prey abundance and lack of food in the nest (Masman et al., 1988; Masman et al., 1989). Both Rijnsdorp et al. (1981) and Village (1983a) showed that the use of flight hunting was positively correlated with wind speed. The explanation is that when there was wind the kestrel could use the uplift to hover in the air and use less energy than with no wind. In rain, fog, very little or very much wind the kestrels were less likely to be flight hunting (Rijnsdorp et al., 1981). Rijnsdorp et al. (1981) also suggested that the kestrel adjust the time of flight hunting to periods of the day with high expected probability of prey capture, e.g. periods of higher activity in voles. I found that solar height was the only factor explaining whether the male kestrels perched or hovered. If the sky is clear it is most light at mid-day. The fact that the kestrels flight hunted less in rainy or foggy weather (Rijnsdorp et al., 1981) could support the teory that light has an influence on hunting behaviour, and would be in accordance with my results. I found no relation between wind and hovering in my study, but I believe this to be due to very few windy days during my study period. On the few days with wind it seemed to me that the kestrels were more frequently hovering. Another possible explanation may be that there were generally more wind and uplift at noon. This was not possible to test, since I did not measure variation in wind through the day. However, it seemed to be less wind in the morning than later in the day (pers. obs.).

CONCLUSION

I found that the three male kestrels in my study had similar home range sizes as found in the only other study of home range in kestrels. I also found that the kestrels preferred open habitats, such as different types of bog and clear cuts, that fright distance was related to amount of bog in the home range and distance to the nest, and that solar height explained whether a kestrel was hovering or perching. Generally I am reserved drawing very strong conclusions from any of my findings, considering that they are based on only three individuals. However, most results points in the same direction as results from other studies on the kestrel. It would have been interesting to do the same study at lower vole densities to see if the home range sizes alters. I would also recommend future studies to include more kestrels to get a larger data set in order to be able to draw more certain conclusions.

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