

NORWEGIAN UNIVERSITY OF LIFE SCIENCES



## Preface

The opportunity to be the first to attempt connecting video monitoring and radio telemetry, and through these methods investigate the connection between habitat and prey selection, has been truly fascinating, and at times frustrating.

I would like to direct my sincere thanks to my supervisor Geir A. Sonerud, who through the entire work with this thesis has been a sorely needed constant and a source of invaluable help. Ronny Steen also deserves my thanks for helping with fieldwork and contributing however he could whenever he could. And also a thanks to Ole Petter Blestad and Bjørn E. Foyn for giving us access to their nest boxes.

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Mikkel Emil Christensen

## Abstract

In this study I used a combination of video monitoring and high intensity radio telemetry to assign specific prey items to habitat visited by female Eurasian kestrels (*Falco tinnunculus*) during the breeding season of 2011 in Trysil, eastern Norway. I used the combined dataset comprising 63 locations reliably paired with prey items taken by five female kestrels to investigate: (1) The probability of a prey item belonging to family Cricetidae and genus *Microtus* in four observed and four map-derived habitat variables. (2) The relationship between search time and habitat, and between search and transport time and visited habitat's distance from nest. (3) The effect of habitat on observation's distance from nest.

High vole abundance and error in assignment of habitat resulted in no detected relationship between habitat and prey type. Search time was not explained by habitat, but was affected near significantly by distance from nest; females used relatively more time at observations closer to the nest than further away, indicating non-hunting behavior, or complex flight patterns. Transport time was not explained by any tested variable, whereas the relationship between distance from nest and habitat described available perching habitat closely.

I conclude that assuming no relationship between habitat selection and prey selection risks type II error, that the method needs further testing and, should be implemented in a vole abundance low-year.

## Sammendrag

I denne pilotstudien kombinerer jeg videoovervåkning av reirkasser og radio telemetri for å koble spesifikke bytter mot habitater besøkt av tårnfalkhunner (*Falco tinnunculus*) i Trysil, hekkesesongen 2011. Jeg benytter det resulterende datasettet på 63 pålitelige bytte-posisjon-par til å undersøke følgende: (1) Sannsynlighet for at et fanget bytte tilhører enten familien Cricetidae eller slekten *Microtus* i et gitt habitat. (2) Forholdet mellom søketid og habitat, og mellom søketid og distanse fra reir, samt forholdet mellom transporttid og distanse fra reir. (3) Forholdet mellom habitatbruk og distanse fra reir.

Grunnet høy smågnagerbestand kombinert med en metodefeil i habitatgruppering kunne jeg ikke påvise et forhold mellom habitat og byttetype. Søketid kunne ikke forklare av habitat men viste et nær signifikant forhold med avstand fra reir; Hunnene brukte relativt mer tid mellom leveranse og byttefangst ved posisjoner nære reiret, som indikerte atferd utenom fødesøk, eller et komplekst fluktmønster. Transporttid kunne ikke forklare av noen av de testede variablene. Avstand fra reir var signifikant knyttet til habitat, og beskrev det tilgjengelige «sittehabitatet» i relativ detalj.

Jeg konkluderer med at ved å anta fravær av forhold mellom habitatseleksjon og bytteseleksjon risikerer man type 2 feil, og at metoden krever videreutvikling, og bør testes en sesong med lave smågnagerbestander.

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# 1. Introduction

According to foraging theory, mobile predators, such as raptors, should focus their hunting efforts toward the habitat and prey type that offers the highest net intake of energy (Sonerud & Steen 2010; Stephens & Krebs 1986). Although studies of quality and profitability of habitats with regard to habitat selection have traditionally focused on prey abundance (Jones 2001), habitat features such as vegetation cover may affect the availability of the prey (e.g. Casagrande et al. 2008; Valkama et al. 1995; Widén 1994). As such, prey availability in a given habitat is a better measurement of habitat quality.

As conservation and management of raptor populations has received greater attention, habitat studies on raptors have become increasingly common (Lohmus 2003). Studies using radio telemetry to accurately assess habitat selection and home range are conducted more often (e.g. Braathen 2009; Casagrande et al. 2008; Larsen 2012; Løken 2009; Village 1982), though most studies are still based on visual observation alone, and performed in areas where the raptors are easily spotted (e.g. Redpath 1992; Valkama et al. 1995).

Raptor diet, however, has been studied for a long time, with different degrees of accuracy. The most common method has been examination of prey remains and pellets at nests (Lewis et al. 2004; Redpath et al. 2001), which tend to over-represent large over small prey and mammalian over avian prey, respectively. Recently, video monitoring prey deliveries to nest have become available and several studies show this to be a superior method of assessing diet (e.g. Lewis et al. 2004; Sonerud & Steen 2010; Steen 2009; Steen et al. 2011), and recent improvements implementing event-triggered video monitoring has been demonstrated by Steen (2009). Though this method risks underestimating the contribution of smaller prey items, as they could, to a greater degree be eaten at the capture site (Sonerud 1992), generally it is the most accurate method available for estimating prey capture rates, and provides a good estimation of prey selection.

Combining habitat selection and prey selection data provides the possibility of assessing the importance of different habitats in relation to specific prey types. This has been done combining analyses of prey remains and pellets with radio telemetry data and observation of hunting habitat (e.g. Casagrande et al. 2008), but to my knowledge, has never been attempted combining intensive radio telemetry tracking and event-triggered video monitoring at the nest.

The Eurasian kestrel (*Falco tinnunculus*), hereafter referred to as the kestrel, is a medium sized falcon (female body mass of c. 220 g) which is abundant in most parts of the western Palearctic (Tømmeraas 1994). In Fennoscandia, the kestrels primary prey are cricetids in general and *Microtus* voles in particular (Cramp & Simmons 1980; Sonerud & Steen 2010), but the kestrel displays a wide variety of alternative prey (Village 1990), and has different primary prey in other parts of the world (Souttou et al. 2007; Van Zyl 1994). In Norway the kestrel is partially migratory and breeds in most parts of the country (Tømmeraas 1994). It uses a wide variety of habitats but is a predominately an open-habitat raptor (Village 1990). The male kestrel provides for the female and the offspring until approximately ten days after hatching (Cramp & Simmons 1980), and even after the female starts hunting the male will generally deliver prey items to the female and not to the young, the female preparing prey items and feeding the nestlings. The kestrel is well suited to both radio telemetry studies, as it hunts in open habitats and thus is relatively easy to follow, and video monitoring studies, as it is tolerant to human disturbance and readily accepts artificial nest boxes, making it easier to capture and monitor (Steen 2010; Village 1990).

Data gathered by Sonerud and Steen (2010) indicated a functional response to abundance of voles (Cricetidae) in the kestrel, and a corresponding decline in avian prey. If the kestrel uses different types of habitat to catch these different types of prey, the between year differences in diet would imply a variation in habitat selection (Lohmus 2003).

In this thesis I combine radio telemetry data and event-triggered video monitoring of prey deliveries at nest for five female kestrels in the breeding season of 2011. The main goal with my study was to investigate possible effects of habitat utilization on the taxa of captured prey items. The secondary goal was to explore some of the possibilities in pairing these methods. I evaluate the method, and its application in estimating foraging behavior.

## **2. Methods**

### **2.1 Study area**

This thesis is based on video monitoring and radio telemetry studies conducted synchronously in Flendalen, Trysil Municipality (UTM Zone 33V 351500-358000, 6808000-6829000), between June and August of 2011. The study area consists of predominately managed coniferous forest with a large proportion of clear-cut areas and bogs, and only small patches of agricultural land. The project was given access to more than 300 nest boxes by local ornithologists, of these six of the locations used by kestrels were included in the study. From north to south, these locations will hereafter be referred to as Bryn, Flenvoll, Tørråsen, Husfliden, Storflendammen, and Storfallet.

### **2.2 Video monitoring**

Event-triggered video recording was used to monitor prey deliveries at the nests, which provides time of delivery, and can also provide more accurate measurements of diet and prey delivery rates than traditional diet assessment methods (Lewis et al. 2004). A small CCD (charge-coupled device) camera with a wide-angle lens was mounted in an upper back corner of each nest box and pointed towards the entrance. The camera was connected to a mini-DVR (digital video recorder) using a long video cable, which uses SD-cards to store data. The entire system was powered by a sealed marine 12V DC lead battery, and operated using a portable LCD screen. The mini-DVR was programmed to record a 5 s video sequence when it registered an object moving in a specific region of the area covered by the lens. For more detailed specifications on the monitoring system, see Steen (2009).

The six nest boxes were checked regularly to determine brood age (i.e. age of the youngest nestling). Video monitoring equipment was installed in the nest box when the broods were, on average, 7.5 days old (range 5-13 days), when the nestlings were considered to be able to thermoregulate (Village 1990). At all nests the female returned and displayed normal behavior almost immediately after the disturbance.

Prey deliveries were monitored both before and after the female kestrels were fitted with radio transmitters, but only prey deliveries occurring while the females were tracked are used in this thesis. The mini-DVRs recorded as expected at all locations before tagging. After tagging



however, the system at Storflendammen malfunctioned due to compatibility problems with the SD-card, resulting in the loss of Storflendammen as a study site for this thesis.

### **2.3 Trapping and radio tagging**

The original project plan included tracking both males and females at each nest, but the males were abandoned from the project after attempts to capture them failed. The female kestrels were trapped for mounting radio tagging when the broods were c. 11 days old (youngest 7 days old and the oldest 14 days old).

Five of the six females were captured using a tunnel trap mounted on the nest box. This trap consisted of a rectangular short tunnel of similar dimensions as the nest box, and was mounted at the nest-box entrance. The trap was equipped with a swing door that was held up by a trigger which could be released by pulling a wire from a hide. When the door swung shut behind the entering kestrel it was held in place by magnets fastened to the door, and an observer climbed up to the nest to retrieve the kestrel for radio tagging.

The female at Storfallet was captured using a Bal-Chatri trap (Berger & Mueller 1959), a double-walled cage made of chicken wire (approx. 40 cm x 30 cm x 20 cm) that was equipped on the outside with many small hangman knot loops of nylon fishing line. A small rodent was placed inside the cage to pose as prey, in this case, one of six dwarf hamsters (four *Phodopus campbelli* and two *P. roborovskii*). As a raptor would try taking the rodent inside the cage, its tarsi would be caught in the nylon loops. When using this trap, an observer was always watching from a hide, and no hamster was in the trap for more than two consecutive hours. When the kestrel struck and was caught in the trap, two observers immediately disarmed the trap and retrieved the kestrel for radio tagging

Each of the captured kestrels was fitted with a radio transmitter mounted at the base of a central tail feather, with the antenna directed backwards along the tail feather shaft. The transmitter was glued onto one feather, tied in place with string to the base of the two central tail feathers, and the antenna was sewn in place along the feather shaft. This is a standard attachment method for radio transmitters on kestrels in particular, and on diurnal raptors in general, described more thoroughly by Kenward (1978). The advantage of this method was that the transmitter was shed when the bird molted. The transmitter weighed c. 3 g which, assuming the female kestrel weighs between 220 and 250 g (Dijkstra et al. 1988; Village 1990), amounts to less than 1.5 % of the birds body mass. The generally accepted upper limit

of experimental equipment for birds is 5 % of body mass for smaller birds, and 2 % for larger birds (Murray & Fuller 2000; White & Garrott 1990).

Few studies have shown adverse effects of tail-mounted radio transmitters on birds (Calvo & Furness 1992; Murray & Fuller 2000). Hiraldo et al. (1994) found no significant effect of radio tagging on prey delivery rates, mortality or reproduction of 14 adult lesser kestrels (*Falco naumanni*) with tail-mounted radio transmitters comprising 3.0 % and 3.5 % of body mass for males and females, respectively. All kestrels tagged with radio transmitters for this study resumed normal behavior shortly after they were released. No signs of irritation towards the transmitter were detected reviewing the video data, and all nestlings present at the time of capture survived to fledge. Considering this, I assume any effect of the transmitters on the kestrels and their behavior to be insignificant.

Outside of the trapping attempts, the hamsters were treated as pets. Permission to conduct trapping, handling, tagging and follow-up of all radio-tagged individuals was given by the Directorate for Nature Management and the National Animal Research Authority of Norway, and all procedures were conducted in accordance with the ethical standards provided by these two entities.

## **2.4 Radio telemetry**

The female kestrels were tracked using handheld Yagi antennas, and either Televilt RX-81 (Televilt, Sweden) or Telonics TR-2 (Telonics, USA) receivers, and coordinates were recorded using one of three different Garmin handheld GPS models (GPSMap 62S, eTrex or GPS 12, Garmin International, USA). To effectively track the kestrel, the study area for each nest was divided between the observers, initially based on cardinal directions in relation to the nest, but as the observers grew more familiar with the area, based on topography and perceived hunting areas. At any time during tracking, 2-4 observers were following the kestrel, with the addition of one observer monitoring the nest from a hide or from a car (where possible) to detect possible prey transfer from male to female outside the nest box. At Tørråsen, no such observer was present due to aberrant behavior of the female when observers were in the vicinity of the nest.

The observers followed the signal until the bird could be located visually by eyesight or binoculars, the signal turned rapidly in another direction, or until the observer was unable to follow due to topographical elements such as rivers or other impassable boundaries. When the

kestrel was located visually, the observer would note the time (in minutes) and wait until the kestrel left (if perching) then walk up to the point and take UTM coordinates for the position. If the signal suddenly turned, the kestrel was spotted at a distance, or the observer was unable to follow, the coordinates for an approximation of the occupied point would be noted and marked as either an unseen or a visual “range plot” (minimum outer range point). Tracking observers would stop and wait if the kestrel approached the nest. At Tørråsen a few observations were made of the kestrel perching on the other side of an electrified bear fence, in these cases the observer estimated the distance to the perch and used the GPS to assign a projected coordinate value (these were marked as visual range observations).

At each point the observer registered the following variables: habitat type (according to Fremstad (1998)), forest age (class 1-5), habitat structure (open, medium or dense), forest height (m), dominating tree (spruce (*Picea abies*), pine (*Pinus sylvestris*) or birch (*Betula pubescens*)), distance to open and closed habitat (m), habitat state (managed or natural), behavior (perching, hovering or flight), perch type (spruce, pine or birch), perch height (absolute and relative (m)), fright distance (recorded if the bird was scared off by the observer (m)), sun (yes or no), precipitation (yes or no), cloud cover (cloudless, partly clouded or clouded), temperature (°C) and wind (no, moderate or strong wind). In the case of habitat structure, open habitat was defined as having a distance between trees greater than the forest height, medium habitat as having a distance between trees of between forest height and half forest height, and dense as having a distance between trees less than half the forest height. If the point was at an edge between two different habitats, both of these were recorded.

## **2.5 Data management**

### **2.5.1 Prey identification**

As the nestlings grew older, larger and more active, the video monitoring system was triggered more frequently without prey deliveries occurring, resulting in a large amount of sequences not containing prey delivery data, and only c. 2.13 % of all video files (n = 12871 sequences) were related to prey deliveries. To separate prey deliveries from nestling-triggered video, I thoroughly watched every clip and picked out all that either showed the arrival of a kestrel with prey, or could improve prey identification (e.g. prey handling by nestlings). The resulting clips were examined thoroughly frame by frame by myself and Geir A. Sonerud, assisted by Vidar Selås and Ronny Steen when there was doubt, using a projector to enlarge

the video. Most mammalian prey items were identified to species or genus level, all lizards and frogs were identified to species, and birds were identified to genus or family. In addition to prey taxon, we registered the sex of the kestrel and whether the prey was decapitated, flayed or otherwise manipulated at time of delivery. In one instance at Flenvoll, the camera had failed to record a delivery seen by the observer at the nest, but we were able to see a prey item on the nest floor that had not been present before the last delivery, was of the same species as the last prey item, and appeared next to the previous prey item in a video frame. This item was included and identified to species level, based on the observer's notes.

### **2.5.2 Tracking data and GIS analyses**

The tracking data was digitalized and imported to ArcMap<sup>®</sup> 10 (ESRI 2010) for initial analysis. There was a risk of an observer effect in the registered observed habitat due to varying levels of experience with habitat registration. Considering this, I created 15 m radius buffer zones around each registered point and created an intersect between the buffer zones and the original points. This allowed me to compare observed habitat between points placed close together, in addition I used "Norge i bilder" (Norge Digitalt 2012) as a background map (through a WMS server) allowing me to use fairly recent aerial photography as a reference. I used this combined dataset to remove inconsistencies in observed habitat between different observers, leaving a dataset without observer bias, or arguably biased towards myself as observer.

The observed habitat type was converted by Cathrine S. Torjussen Larsen (see Larsen 2012) into a variable for productivity (from zero to four, where zero is the poorest and cannot support trees, and four is the richest) and a simpler variable for habitat type (bog, bog with trees, coniferous forest, mixed forest, infrastructure, and agriculture), both of which I adopted. This gave me four habitat variables: Habitat type, productivity, forest age, and habitat structure. Every observation point was given two sets of observed habitat variables: habitat 1 and habitat 2. These represent the two different habitats if an observation was made within 10 m of another habitat, if there was no such edge both habitats were assigned the same values. Due to the tendency of kestrels to hunt in open habitat (Village 1990), habitat 1 was assigned to be the more open of the two alternatives. In the event that both habitats were open, the tendency of the habitat types to be open decided which of the two should be assigned to either habitat 1 or 2. E.g. bog has a higher tendency to be open than forest, even if the forest is now a clearcut).

In addition to using observed habitat, I extracted habitat data from a digital detailed area resource map (“AR5” (The Norwegian Forest and Landscape Institute 2011)), using 10 m radius buffer zones to intersect against the map. The habitat variables exported from the map were: habitat type (forest or bog), tree type (coniferous, mixed or deciduous), productivity (impediment, low or medium), and soil type (mineral or organic). Where more than one habitat intersected the buffer, both were kept, resulting in a habitat 1 and a habitat 2 for map derived habitats as well, where habitat 1 is the habitat with the highest percentage within the buffer. Lastly I calculated distance from nest for every observation using the “Near” in ArcMap® 10.

### **2.5.3 Pairing tracking and video data**

Pairing of the prey delivery data and the radio telemetry data was done manually by comparing time of delivery at nest, time of departure from nest, time at the start of an observation and time at the end of an observation. In this work it quickly became apparent that there was an accuracy issue with regards to time measurements. This had the following reasons: (1) Observers had several clocks that were used promiscuously, resulting in poor synchronization. (2) Poor routine with regard to reaction when the kestrel was spotted. One should always take the time immediately when spotting the kestrel, and when the kestrel left. This was not always the case as some observers used clocks carried in pockets, or started to take notes before registering the time. (3) The time was taken at the level of minutes. Because the kestrel can travel c. 300 m in half a minute (G. A. Sonerud, unpublished data), thus time should clearly be measured in seconds. (4) The time of the recording system was calibrated each day by the observer doing the setup (mostly, but not always, myself), resulting in individual difference in time between the camera and each observer’s clock.

To overcome the time-accuracy issues I calculated the mean difference in time between the camera and each observer’s clock for each nest, using observations at nest as the link between the observer’s clock and the camera. This gave me a “time of observation 2” which was used only as a help in deciding which observations could be linked to each prey delivery. In addition I used the comments made by each observer and, I used ArcMap® 10 to see where each observation was relative to the others. Together, this provided enough data to select the observations that were the last known position of the kestrel before a prey delivery.

To assess the quality of the pairing between observation's and prey deliveries I assigned a value to each paired observation based on the quality of the pairing: (1) no problem, (2) prey transfer from male to female, (3) uncertain coordinates (assigned to range observations and estimated points), (4) uncertain time of observation (assigned to observations where the observer forgot to note time, and time was estimated based on notes and time on the GPS device), (5) unknown sex at delivery, (6) time difference too great (assigned to observations where more than 30 minutes had passed between end of observation and delivery on nest, if the position of the kestrel was not known in the time between), (7) last plot was previous delivery, and (8) no previous plot.

By calculating the time difference between the kestrel's departure from the nest box after last delivery and the start of the observation paired to the next delivery, I estimated search time for each prey item possible, i.e. every reliably paired observation where the last delivery was known. Transport time was estimated calculating the difference between end time of the paired observation and time of arrival at nest.

## 2.6 Statistical analyses

Initial exploratory statistical analyses were performed with the software JMP<sup>®</sup> version 9 (SAS Institute Inc. 2010). Based on these analyses I found that the dataset lacked the power necessary to perform analyses on prey type other than *Microtus* voles vs. all other prey, or family Cricetidae vs. all other prey. The result was that for further analyses, prey type would be a binomial variable: *Microtus* (Yes/No) and Cricetidae (Yes/No). I also found that certain categories of the observed habitat variables should be pooled, the result being the following compressed variables: habitat type (bog or forest), productivity (low, medium or high), habitat structure (open, closed), and forest age (young, old).

Further statistical analyses were performed using the software R version 2.15.0 (R Development Core Team 2012) in the platform RStudio (The RStudio Project 2011). Tables were made in Excel<sup>®</sup> (Microsoft 2010) and figures were made using SigmaPlot Version 12.0. I used the logistic regression function of the "lmer"-command in the lme4 package in R (Bates et al. 2011) to test for relationships between prey type (*Microtus* voles or other prey, and cricetids or other prey) as response variable and all available habitat categories (explanatory variables) separately with nest ID as a random category.

Using a linear mixed effects model (lme) in the nlme package (Pinheiro et al. 2012) in R, I tested for (1) effects of compressed observed habitat categories (explanatory variables) on search time and distance from nest (response variables); and (2) effects of distance from nest (explanatory variable) on search time and transport time (response variables). Search time, transport time and distance from nest were  $\log_{10}$ -transformed to improve linear fit of the models and to obtain approximate normal distribution. In all tests, nest ID was implemented as a random variable.

Each model was run several times testing all possible categories as intercept parameters. The dataset for all tests contained only quality values one, three and four. For tests on habitat no unseen range observations were included. Datasets for analyses on genus level were restricted by only including reliable *Microtus* yes or no observations. In all models on habitat, and in all on models prey type, I looked for significant difference between the parameters of the explanatory variable, and in addition I looked for difference in AIC values between habitat 1 and habitat 2, to determine which of the two habitat possibilities gave the best fit of the model.

## 3. Results

### 3.1 General

Only three of the nests had confirmed deliveries by the male at the nest box, during tracking. At Flenvoll and Tørråsen the male was never reliably recorded at the nest while observers tracked the female. The kestrel females were recorded delivering a total of 105 prey items while the observers were tracking, of which 95 prey items were possible to identify to at least family, 63 to genus, and 53 to species. Of the 89 prey items belonging to family Cricetidae, 21 could not be identified further, and 9 were categorized as belonging to one of two different genera, 40 prey items were identified as *Microtus* voles, whereas only 10, 8 and 1 were identified as *Myodes*, *Myopus*, and *Lemmus*, respectively (table 1). I was able to reliably pair 63 prey items delivered by the female with observations from tracking data. Depending on whether the observation was a range observation and to which taxonomic level the prey item could be identified, paired observations were assigned to several datasets designed for different analyses. This was done to be able to conduct each analysis on all available observations (Table 1).

For all habitat variables in tests on family level and for all variables but one on genus level, habitat 1 had either lower AIC than habitat 2, or the difference was too small to detect a significant difference, i.e.  $\Delta AIC < 2.0$  (see appendices 1-4). The AIC for the map-derived forest productivity variable was significantly lower for habitat 2 than for habitat 1 (difference = 4.87), however, due to the fact that the kestrel hunted primarily in open habitat and all other tests either had the opposite or no difference, I will focus on habitat 1 from here on. In all datasets the complete variable of forest age had too few observations in total and lacked “no-observations” in one or more category, the result being that no reliable analyses were possible using this variable (see appendix 1).



**Table 1.** Number of prey items delivered by the kestrel females and the occurrence of prey items in datasets for different analyses, in observed habitat variables (<sup>1</sup>) and categories, and in habitat variables (<sup>2</sup>) and categories derived from electronic maps.

Variable	<i>Microtus</i>	<i>Myopus</i>	<i>Myodes</i>	<i>Lemmus</i>	Unknown cricetids	Cricetidae	Other	Unknown	Total (n)
<b>Analysis of effect of:</b>									
Habitat on prey item (family)	27	4	3	0	15	49	2	0	51
Habitat on prey item (genus)	27	4	3	0	0	34	2	0	36
Habitat on search time	22	3	2	0	12	39	2	4	45
Habitat on distance from nest	27	4	3	0	15	49	2	5	56
Prey item (genus) on search time	24	3	4	0	0	31	4	0	35
Prey item (genus) on distance from nest	30	5	5	0	0	40	4	0	44
Distance from nest on search time	24	3	4	0	14	45	4	4	53
Distance from nest on transport time	27	5	5	0	16	53	4	6	63
<b>Habitat type<sup>1</sup></b>									
Coniferous	17	1	4	0	7	29	2	2	33
Mixed	3	0	1	0	1	5	0	0	5
Bog	10	2	0	0	6	18	2	4	24
Treed bog	0	1	0	0	3	4	0	0	4
Infrastructure	0	0	0	0	1	1	0	0	1
Agriculture	0	1	0	0	0	1	0	0	1
<b>Productivity<sup>1</sup></b>									
0	10	2	0	0	6	18	2	5	25
1	1	2	0	0	2	5	1	0	6
2	2	0	0	0	2	4	0	0	4
3	12	1	4	0	6	23	1	1	25
4	5	0	1	0	1	7	0	0	7
<b>Forest age<sup>1</sup></b>									
class 1	2	0	0	0	1	3	0	2	5
class 2	6	0	1	0	1	8	0	0	8
class 3	3	0	1	0	4	8	1	0	9
class 4	0	0	1	0	1	2	1	0	3
class 5	7	1	2	0	2	12	0	0	12
<b>Habitat structure<sup>1</sup></b>									
Open	19	4	2	0	13	38	2	6	46
Medium	7	0	2	0	4	13	2	0	15
Dense	4	1	1	0	1	7	0	0	7
<b>Habitat type<sup>2</sup></b>									
Forest	20	2	5	0	11	38	2	3	43
Bog	9	3	0	0	7	19	2	3	24
<b>Soil type<sup>2</sup></b>									
Mineral	18	2	5	0	10	35	2	1	38
Organic	11	3	0	0	8	22	2	5	29
<b>Tree type<sup>2</sup></b>									
Coniferous	16	2	4	0	11	33	2	2	37
Mixed	4	0	1	0	2	7	0	1	8
None	9	2	0	0	5	16	2	3	21
<b>Productivity<sup>2</sup></b>									
Impediment	13	4	0	0	9	26	2	4	32
Low	9	1	3	0	5	18	2	0	20
Medium	7	0	2	0	4	13	0	2	15
<b>All prey items delivered by females</b>	<b>40</b>	<b>8</b>	<b>10</b>	<b>1</b>	<b>30</b>	<b>89</b>	<b>6</b>	<b>10</b>	<b>105</b>

## 3.2 Prey selection in different habitats

### **Cricetids vs. other prey**

The probability that a captured prey item was a cricetid did not differ significantly between different habitat categories for any habitat variable (appendices 1 and 2). In all uncompressed observed habitat variables, and in the compressed observed productivity variable, one or more of the categories had no observations of non-cricetid prey items, leaving the models unreliable. In the productivity variable the category “high” was excluded, and in the resulting variable, and in all other compressed observed variables (excepting forest age), the probability of a prey item being a cricetid significantly differed from the probability of other prey items (appendix 1).

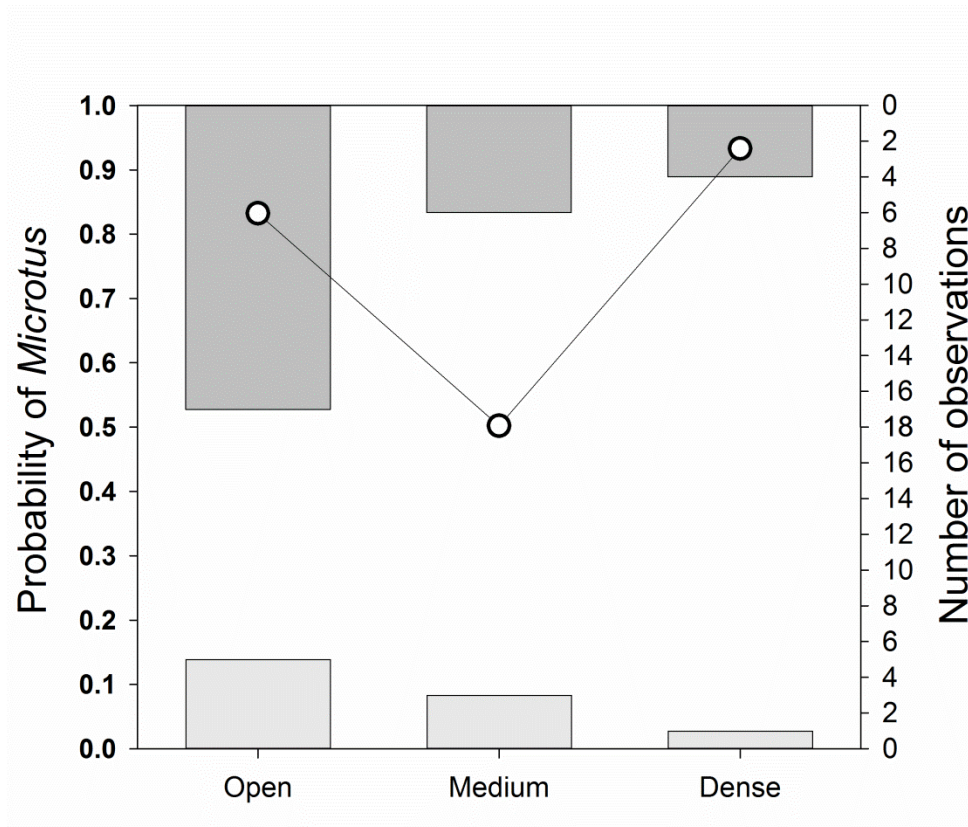
For the map-derived variables, the probabilities of captured prey item being a cricetid significantly differed from that of non-cricetids in both categories of the habitat type and in both soil type categories. However, prey selection did not vary between categories within variables (appendix 2). This was also true for the productivity and tree type variables, though these variables each had one category with no non-cricetid observations, leaving them unreliable.

### ***Microtus* vs. other prey**

Of the complete observed habitat variables only habitat structure had non-*Microtus* prey observed in all categories (appendix 3), and within this variable the categories “dense” and “open” were near significant ( $p > 0.10$ ) and showed a trend towards difference between these and the category “medium” (Table 2, Figure 1). This trend may have been an artifact caused by the insignificance of the “medium” category.

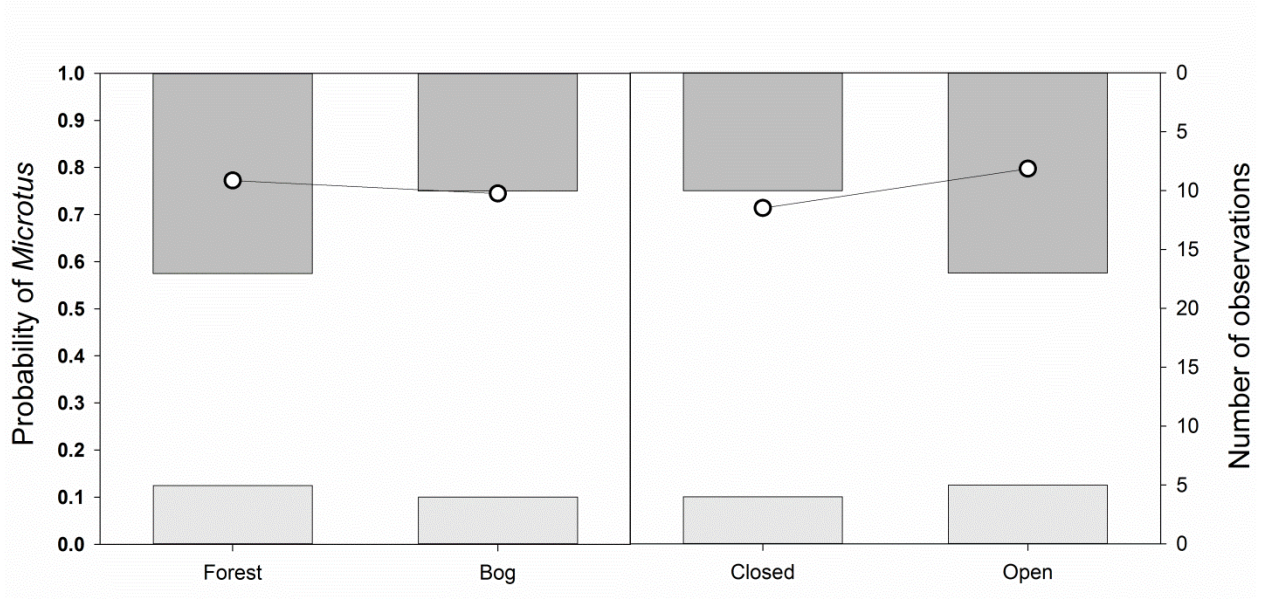
**Table 2.** Logistic regression model of the probability that a captured prey item was a *Microtus* vole if the last observation of the female was in a given habitat category within a given variable. Parameter estimates are given for each category as parameter intercept, nest ID was included as a random variable. n = 36 over 5 nests for all observed habitat variables except forest age (n = 15, 5 nests). Habitat variables derived from maps had n = 34 over 5 nests

Explanatory variable	Model estimate	SE	P	Estimated probability of <i>Microtus</i>
<i>Productivity (compressed)</i>				
Low	-1.3636	0.7264	0.061	0.80
Medium	-1.0357	0.7034	0.14	0.74
High	-1.0013	1.3255	0.45	0.73
<i>Habitat type (compressed)</i>				
Bog	-1.0703	0.7373	0.15	0.74
Forest	-1.2215	0.6216	<b>0.049</b>	0.77
<i>Habitat structure</i>				
Open	-1.6012	0.8876	0.071	0.83
Medium	-2.6310	1.0095	0.99	0.50
Dense	-0.0088	1.4650	0.073	0.93
<i>Habitat structure (compressed)</i>				
Open	-1.3644	0.6552	<b>0.037</b>	0.80
Closed	-0.9096	0.7144	0.20	0.71
<i>Forest age (compressed)</i>				
Young	-0.4055	0.9129	0.66	0.60
Old	-0.8473	0.6901	0.22	0.70
<i>Habitat type from map</i>				
Bog	-1.1610	0.7245	0.11	0.76
Forest	-1.2180	0.5597	<b>0.030</b>	0.77
<i>Soil type from map</i>				
Mineral	-1.0825	0.5822	0.063	0.75
Organic	-1.3940	0.7190	0.053	0.80
<i>Forest productivity from map</i>				
Impediment	-1.4525	0.7585	0.056	0.81
Low	-0.4778	0.7177	0.51	0.62
Medium	-2.1290	1.1650	0.068	0.89
<i>Tree type from map</i>				
Coniferous	-1.0151	0.5816	0.081	0.71
Mixed	-1.1892	1.2065	0.32	0.74
None	-1.5750	0.8398	0.061	0.90



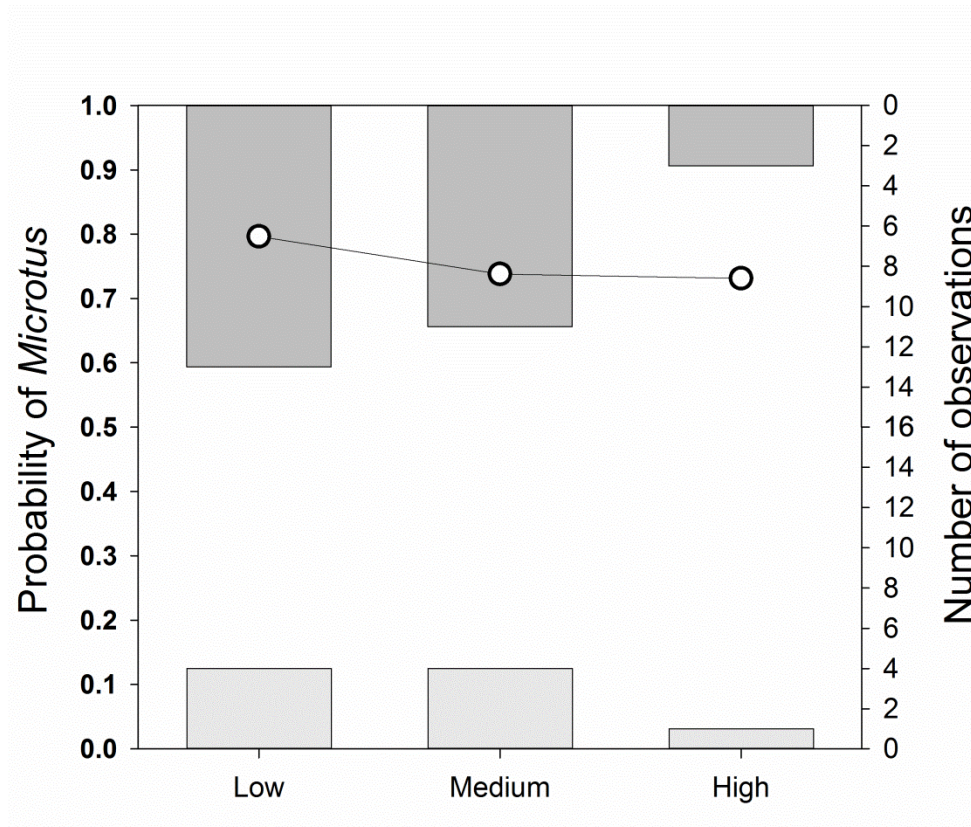
**Figure 1.** Estimated probability of a captured prey item being a *Microtus* vole, if the prey item was captured in open, medium or dense habitat (dots), and number of observations of *Microtus* voles (dark bars) and other prey items (light bars). Probabilities are calculated from the parameter estimates of the logistic regression model ( $n = 36$ , random effects = 5 nests,  $p = 0.071$  (open),  $p = 0.99$  (medium),  $p = 0.073$  (dense)).

The categories “forest” and “open” in the compressed variables habitat type and habitat structure, respectively, showed significance in selection of *Microtus* prey over other prey item. The remaining category in each of these variables was insignificant however, and the test did not detect a difference between categories within each variable (Figure 2, appendix 3).



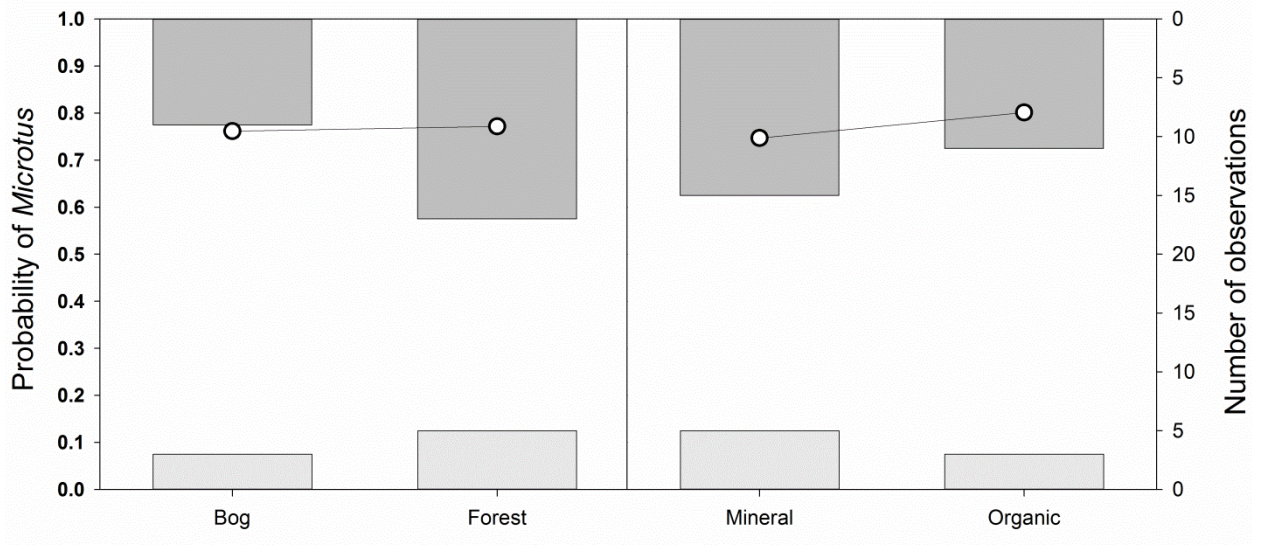
**Figure 2.** Estimated probability that captured prey was a *Microtus* vole (dots) in the compressed variables habitat type (left) and habitat structure (right), and number of paired observations featuring captured *Microtus* voles (dark bars) and other prey (light bars) ( $n = 36$ , random effects = 5 nests,  $p = 0.1470$  (bog),  $p = 0.049$  (forest),  $p = 0.20$  (closed),  $p = 0.037$  (open))

In the compressed productivity variable, probability of *Microtus* was only near significant in the category “low”, though there was a trend for “medium” productivity, and no difference between categories could be detected (Figure 3, appendix 3).

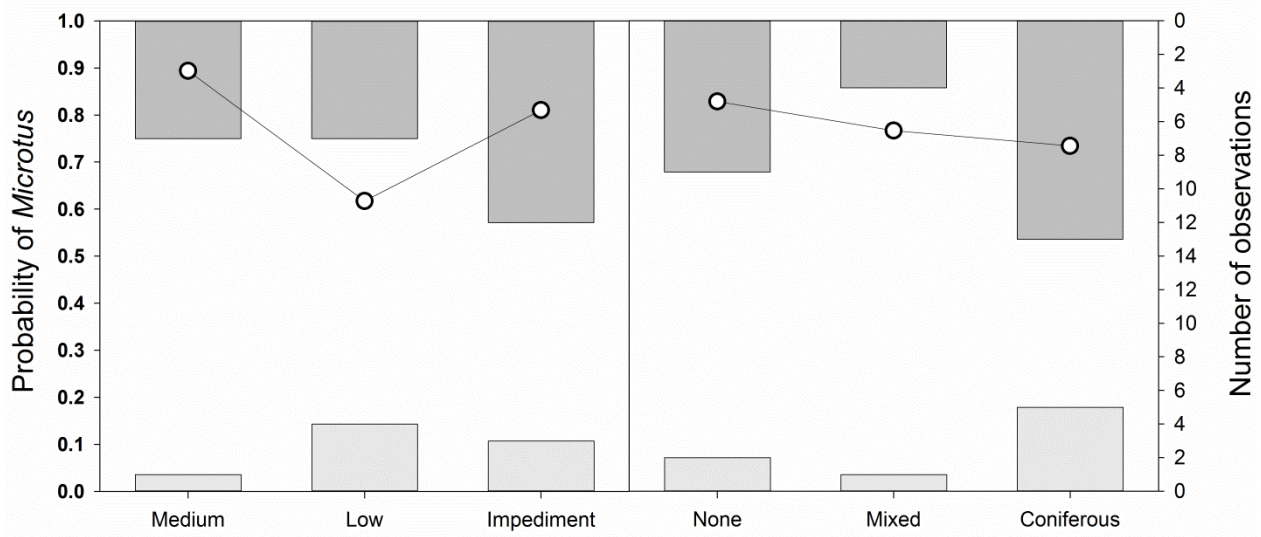


**Figure 3.** Estimated probability of captured prey being a *Microtus* vole if the prey was captured in low, medium or high productivity habitat (dots), and number of observations of *Microtus* (dark bars), and other (light bars) prey. Probabilities are calculated from the parameter estimations of the logistic regression model ( $n = 36$ , random effects = 5 nests,  $p = 0.061$  (low),  $p = 0.14$  (medium),  $p = 0.45$  (high)).

None of the map-derived habitat variables had any significant effect on the probability that the delivered prey item would be a *Microtus* vole (Figure 4, Figure 5, appendix 4). Of all categories within map-derived habitat variables, only “forest” showed a significant difference between probability *Microtus* and other prey, although, excepting “bog” (habitat type), “mixed” (tree type) and “low” (productivity), the other variables would have been significant on a 0.10 significance level (appendix 4).



**Figure 4.** Estimated probability that captured prey was a *Microtus* vole (dots) in the map-derived variables habitat type (left) and soil type (right), and number of paired observations featuring captured *Microtus* voles (dark bars) and other prey (light bars) ( $n = 34$ , random effects = 5 nests,  $p = 0.11$  (bog),  $p = 0.030$  (forest),  $p = 0.063$  (mineral),  $p = 0.053$  (organic)).



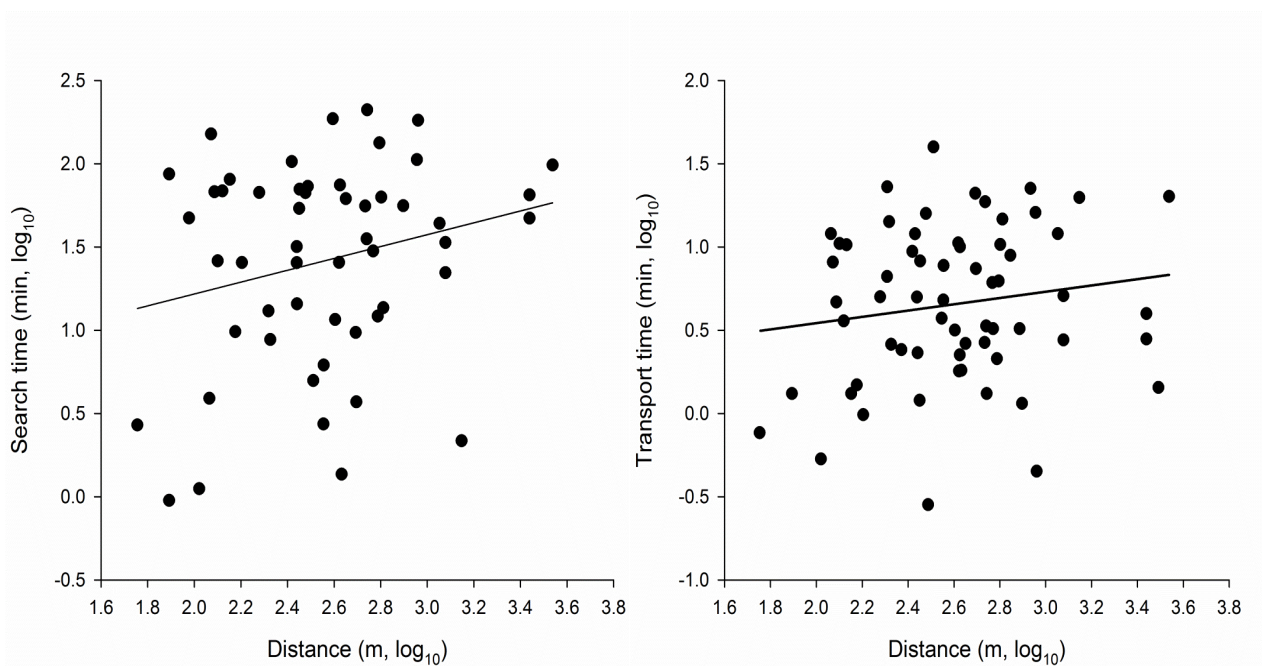
**Figure 5.** Estimated probability that captured prey was a *Microtus* vole (dots) in the map-derived variables productivity (left) and tree type (right), and number of paired observations featuring captured *Microtus* voles (dark bars) and other prey (light bars) ( $n = 34$ , random effects = 5 nests,  $p = 0.068$  (medium),  $p = 0.51$  (low),  $p = 0.056$  (impediment),  $p = 0.061$  (none)  $p = 0.3240$  (mixed),  $p = 0.081$  (coniferous)).

### 3.3 Temporal variables

Search time was not significantly affected by the habitat in which the prey item was assumed to have been captured for any of the categories within compressed variables (appendix 5).

When search time and distance from nest at assumed capture site were  $\log_{10}$ -transformed, a near significant effect of distance from nest at assumed capture site was found on search time.

The female kestrels used longer time, relative to distance from nest, between departure from the nest box and arrival at assumed capture site for observations closer to the nest than for observations further away (Figure 6). No significant effect was found of  $\log_{10}$ -transformed distance from nest on  $\log_{10}$ -transformed transport time, however (Figure 6).



**Figure 6.**  $\log_{10}$  transformed search time (left) and  $\log_{10}$  transformed transport time (right) regressed on the  $\log_{10}$  transformed distance from nest at assumed prey capture sites. The regression lines were calculated from the parameter estimates of the linear mixed effects models (search time:  $y = 0.51 + x \cdot 0.36$ ,  $df = 47$ ,  $p = 0.088$ ,  $n = 53$ , random effect = 5 nests) (transport time:  $y = 0.17 + x \cdot 0.19$ ,  $df = 57$ ,  $p = 0.23$ ,  $n = 63$ , random effect = 5 nests).



### 3.4 Distance from nest

The distance from nest to the presumed capture site, differed significantly depending on the observed habitat (Table 3). Distance from nest when the female kestrels visited high and low productivity habitat differed significantly from the distance at medium productivity habitat, with estimated mean distances of 153 m, 247 m and 395 m, respectively (Table 3). Habitat type explained distance from nest significantly ( $p < 0.05$ ), with estimated mean distances of 340 m in forest habitat and 217 m in bog. Habitat structure was a significant predictor of distance from nest with both the full model, medium and dense habitat being different from open, and the compressed model open habitat differing from closed habitat (Table 3). For habitat structure, the compressed model gave a better fit ( $\Delta AIC = 4.004$ , appendix 6) and had a lower p-value. Prey type (*Microtus* vs. other prey) did not affect distance from nest (Table 3).

**Table 3:** Results from linear mixed effects models with  $\log_{10}$ -transformed distance from nest as response variable, and four observed habitat variables (n = 56, 5 nests) and probability of a prey item being a *Microtus* vole (yes/no, n = 44, 5 nests) explanatory variables, and with nest ID as random variable. Categories in italics are the intercept parameters, p-values in bold signify statistically significant difference between categories at a 0.05 level.

Explanatory variable	Estimate	SE	Df	P	Estimated mean distance from nest (m)
<b>Habitat type (compressed)</b>					
<i>Forest</i>	2.5311	0.1074	50		339
<i>Bog</i>	-0.1927	0.0795	50	<b>0.019</b>	217
<b>Habitat structure (compressed)</b>					
<i>Open</i>	2.3430	0.1095	50		220
<i>Closed</i>	0.3075	0.0713	50	<b>0.0001</b>	447
<b>Productivity (compressed)</b>					
<i>Low</i>	2.3923	0.1031	49		246
Medium	0.2039	0.0760	49	<b>0.010</b>	394
High	-0.2065	0.1502	49	0.18	153
<i>High</i>	2.1857	0.1617	49		
Low	0.2065	0.1502	49	0.18	
Medium	0.4105	0.1479	49	<b>0.0078</b>	
<b>Habitat structure</b>					
<i>Open</i>	2.3396	0.1121	49		218
Medium	0.2961	0.0841	49	<b>0.0009</b>	432
Dense	0.3344	0.1218	49	<b>0.0084</b>	472
<i>Dense</i>	2.6740	0.1453	49		
Open	-0.3344	0.1218	49	<b>0.0084</b>	
Medium	-0.0383	0.1419	49	0.79	
<b><i>Microtus</i></b>					
Yes	2.6372	0.1516	38		433
No	0.0275	0.1249	38	0.83	462

## 4. Discussion

### 4.1 Method

I paired radio telemetry data and prey delivery data successfully, resulting in a dataset that contained observations representing the last known position of the females before the capture of a specific prey item. These paired observations had a weakness in that the female might have moved to another position and hunted there, before returning to the nest, without the observers being able to pinpoint this other location in time. Looking at the transport times in question, however, this did not seem to be a vital issue with this dataset, as most of the observations had relatively short transport times (two thirds were below 10 minutes).

The most important weakness was that the habitat registered at the position may not be the habitat in which the prey was captured. The females were not spotted striking at prey or carrying a prey item at all observations chosen to represent capture sites, and most of the observations were made with the female perching. As the kestrel hunts by striking from a perch or by striking from a hovering position (Village 1990), the prey item would have been captured in the habitat surrounding the registered position. For observations where surrounding habitat differed from perching habitat, this may have resulted in difference between observed habitat and the habitat in which the prey was captured. For some of the observations this difference may have been remediated by the distinction between habitat 1 and 2, defined by more open or more closed habitat for observations at edge between habitats, and defined by majority of habitat registered within buffer zones for map-derived habitats. Nevertheless, this weakness may have been an important source of bias in the analyses.

The issues of accuracy in times measured by the observers, did not affect the pairing of data itself, but added a large amount of work in data management, and may have contributed to loss of potential data points when tracking. A more thorough routine with regard to time measurement and synchronization of clocks could have improved the dataset, at least to the point that the time costs of analyses and data management would have decreased substantially.

## 4.2 General results

For testing effects of several habitat variables in the same model, the paired dataset lacked sufficient number of observations, both in total, and within each habitat category. This lack of statistical power was caused by a low number of available observations, which at least partially would have been remediated if the camera at locality Storflendammen had not malfunctioned.

Additionally the female kestrels delivered too few prey items other than cricetids in general and *Microtus* voles in particular to enable an analysis of the occurrence of other prey in different habitats, likely primarily caused by an abundance of cricetids in general, and *Microtus* voles in particular, which are the kestrel's main prey in northern Europe (Cramp & Simmons 1980; Village 1990). In a study conducted parallel to mine, small mammal abundance was assessed using snap traps within each of the female kestrels' home ranges, and this revealed relatively high densities of *Microtus* voles and bank vole, and a very high density peak in wood lemming (G. A. Sonerud, unpublished data, Støvern 2012).

## 4.3 Prey selection and habitat use

The female kestrels selected few prey types other than cricetids in the period they were tracked. Of 51 paired observations reliably identified to family and available for habitat analyses, only 2 prey items were not cricetids (1 song thrush (*Turdus philomelos*) and 1 common lizard (*Zootoca vivipara*). This imbalance in prey items available for analysis resulted in most of the analyses becoming unreliable, as categories did not contain enough observations of non-cricetid prey. The analyses that did not become unstable (i.e. compressed variables of habitat structure, habitat type, and productivity, and the map derived variables of habitat type and soil type) had significantly higher probability that the prey item was a cricetid than other prey in all categories, and had no difference between categories.

Taking into account the one-sidedness of data available at family level, and the fact that the family Cricetidae is present in all the habitats available in the study area (Hagström et al. 2011; Semb-Johansson 1990; G. A. Sonerud, unpublished data), these results were as expected. In a year with lower densities of cricetid prey one could hypothetically find a difference between habitats used to capture cricetids and other prey, respectively, as the kestrel displays functional response to cricetid prey, and switches to other, less profitable,

prey when availability of cricetids decreases (e.g. Korpimäki 1986; Korpimäki & Norrdahl 1991; Sonerud & Steen 2010).

The estimated probability that a captured prey would be a *Microtus* vole was higher than that of other prey in all compressed habitat variables. However, not all of these estimates were significant. According to my results, if a prey item was captured in forest (both observed habitat type and map-derived), the probability of that item being a *Microtus* vole was significantly higher than the probability of being other prey. This included both clear-cuts and forest with standing trees. In addition, several other habitat categories were near significant (significant at a 0.1 level) including observed low productivity habitat, and all but three of the map derived categories (bog, low productivity, and mixed tree type).

None of my analyses could detect any significant difference in probability of delivered prey being a *Microtus* vole between habitat categories within variables, but the analysis on habitat structure showed a very weak trend towards a difference between medium structure habitat and open and dense habitat. This trend was likely caused by insignificance of the probability estimation for medium habitat, however, and the estimations for open and dense were only significant at a 0.1 significance level.

These results should indicate that the female kestrels used all habitat categories to capture *Microtus* prey, and potentially selected *Microtus* voles over bank voles and wood lemmings in all habitats. The result that *Microtus* voles were selected above other prey, is in accordance with what is generally accepted as the kestrel's primary prey in northern Europe (Village 1990) and particularly in Fennoscandia (e.g. Korpimäki & Norrdahl 1991; Sonerud & Steen 2010; Valkama et al. 1995). As *Microtus* voles generally inhabit open and somewhat moist to wet habitat such as bogs, meadows and clear-cuts (Hagström et al. 2011; Semb-Johansson 1990), the result that the female kestrel captured *Microtus* voles in dense forest habitat is counterintuitive.

Wood lemming, which is primarily an old-forest species, were abundant in all habitats except meadows and bank voles were abundant in forests, whereas *Microtus* voles were not present in the forest type my results imply (G. A. Sonerud, unpublished data). This is clear evidence that at least some of the prey items were assigned to the wrong category within at least one variable, and that the method of assigning habitat categories should be revised.

To rectify the habitat category assignment error two methods are possible. (1) For observed habitat categories, the definition of edge habitats should be broadened, that is; increase the

maximum distance between habitats necessary to qualify as edge habitat, and increase the number of possible registered habitats. I suggest registering edge habitat wherever the position of the bird is within 25 m of another habitat, and increasing number of habitats to four, but still assigning them according to openness of habitat. (2) For map-derived habitats, the buffer zone should be increased to 25 m and number of possible habitats increased to four, and in addition, I suggest to assign categories based on openness of habitat, provided the habitats in question comprise 10 % or more of the area of the buffer zone.

These measures should result in a dataset with higher likelihood of predicting the habitat in which the prey item was captured. The selection of this buffer size is supported by Braathen (2009), and is a compromise between the strike distance of about two times perch height (G. A. Sonerud, pers. comm.), and including too much noise in the dataset. I was not able to implement these changes to the method for my thesis due to time constraints.

#### **4.4 Time**

I could not find any relationship between search time (i.e. time from departure from nest to end of last known observation before prey delivery) and either prey type or habitat. This lack of relationship to habitat may have been caused by the error in habitat category assignment, and should be tested again after the categories have been reassigned.

I analyzed the potential effect of distance from nest at assumed capture site on the time spent from end of the observation until delivery at the nest, but did not find a significant result. If the females generally flew directly to the nest box after prey capture, one would expect a linear relationship between distance from nest and transport time. If most prey items were prepared before delivering at nest, as is common with larger voles or birds (e.g. Steen, Ronny et al. 2010), a linear relationship would also be expected, but with a higher intercept value for transport time. The lack of significant result could be caused by a lack of precision in the dataset, too few observations, pooling data over the course of nestling growth as prey preparation diminishes (Steen, R. et al. 2010), or other variations in behavior. The potential influence of prey preparation on the relationship between transport time and distance from nest should be possible to determine by investigating status of the prey delivered at nest.

My results indicate a near significant relationship between search time and distance from nest. Search time was longer in relation to distance from nest at capture sites closer to the nest, than at those further away from the nest. In effect, this could be caused by three possible events.

(1) When hunting for prey at locations far from the nest, the females could travel directly from the nest to a known area, and start prey search after arrival, the opposite being searching for prey in a pause-travel pattern until encountering a prey item. This would result in a shorter travel time from the nest to the area of the prey capture. (2) The kestrels could move in another pattern than a straight line, for example in a spiral or cross back and forth over the same area. This would result in the kestrel travelling further than distance from nest would imply. (3) The females could display other behavior than prey search to a greater degree near the nest than further away.

The obvious weakness of measuring search time from last prey delivery at nest box to the last known point before prey capture is that all behavior occurring within that time period is included. At any time the kestrel may choose to hunt or to engage in other activities such as preening, digesting, resting or simply doing nothing (Herbers 1981; Masman et al. 1988). Additionally, when a female captures a prey item, she can choose whether to bring it to the nest or to ingest it herself (Sonerud 1989), this would bias the search time in that she may move closer to the nest before capturing the next prey to deliver.

The higher-than-expected search time for near-nest observations is, in my opinion, likely caused by both traveling directly to hunt sites further away, and by larger proportion of non-hunting behavior near the nests. The nature of the females' behavior within the search time should be possible to determine by investigating the pattern of tracking observations between the last delivery at the nest box and their behavior at those observations.

For this thesis it proved impossible to further investigate search and transport time, and their relation to other variables, due to time constraints.

## **4.5 Distance**

Estimated mean distance from nest at last observation before prey delivery was significantly higher for the forest habitat type than for bog, for closed habitat structure than for open (compressed structure gave a better fit than the full model), and for medium productivity habitat than for high and low productivity. Again this should be regarded as occupied habitat rather than prey capture habitat due to the habitat category assignment error. This seems to indicate that the females chose to occupy habitat less suitable for prey capture the further they traveled from the nest (high productivity was only present close to the nest at locality Husfliden and consisted largely of clear-cut areas). However, only location Tørråsen had

observations at bogs further away from the nest than 500 m, and all but one observation of open habitat and low productivity habitat at more than 500 m from the nest also were made at this locality. The other nests all had at least one observation of forest habitat, closed habitat or medium productivity at more than 500 m from the nest. Tørråsen also had the highest number of observations of far-from-nest prey captures, which could be caused by a lower availability of prey items at this nest; this would correspond with the fact that the trapping index of *Microtus* voles was lowest at Tørråsen (Sonerud, G.A, unpublished data).

As the analysis of distance from nest with habitat variables as explanatory variables was conducted with nest ID as a random effect, the effect of open habitat, bogs, and low productivity on distance from nest was lessened, being biased towards Tørråsen. The results of these analyses then simply describe the available perching habitat in the study area. All the nests are situated close to the bottom of a shallow and broad valley, and, with the exception of one specific hunting area at Tørråsen, the kestrel generally moved along a hydrological gradient towards dryer habitat when moving away from the nests, as a result of the topography of the valley.

#### **4.7 Further possibilities**

My thesis was based on data from a peak year in small mammal abundance, and this likely affected the end results in the way of risking a type II error. I could not detect a difference in prey selection across different habitat, spatial or temporal variables. However, as the kestrel has been shown to exhibit functional response to vole abundance (Sonerud & Steen 2010), a possible effect of habitat on prey selection should be masked. Lõhmus (2003) reviewed year effects of habitat use in diurnal raptors and owls, and demonstrated that in many cases such effects are masked by pooling data over successive years. Linking well identified specific prey items with raptor movement, as is only possible to do with a combination of video monitoring and radio telemetry, should be attempted in low years, when alternative prey are more common in the raptors diet. In addition there is a possibility of difference between genders, and as such this should also be repeated for the males.

I was not able to rectify the methodological error in habitat category assignment within the time allotted for this thesis, and further investigation in search time and transport time is possible. An additional analysis I would have liked to have done is investigate the possibility



that the female kestrel returns to the same area after if the last successful prey capture came from that area, i.e. employs a win-stay strategy (Sonerud 1985).

## 4.8 Conclusion

Though I could not find any differences in probability of a given prey taxon between habitats in my thesis, this lack of effect was likely caused by the high availability of the female kestrels primary prey, and compounded by an error in the methods. Given that the error is rectified, this study should be repeated in a *Microtus* low year, to investigate a possible relationship with a better dataset. Using the results generated for this thesis to conclude that the kestrel does not use different habitats for different prey items would run a high risk of type II error.

Combining event-triggered video monitoring and radio-telemetry grants the possibility to investigate relationships between habitat use, time allocation and selection of specific prey items. This is potentially a valuable method to uncover mechanisms behind shifting habitat use between years, and as such, should be further developed.

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# Appendix

## Appendix 1:

Logistic regression models with the probability of a prey item being a cricetid as response variable, observed habitat variables as explanatory variables and with nest ID (5 nests) as a random variable. For all categories n = 51, except forest age (n = 28 in habitat 1 and n = 30 in habitat 2). <sup>c</sup> denotes a compressed category; certain categories from the full model have been pooled. Categories in italics are the intercept parameters, and bold p-values denote significance at 0.05 level.

Explanatory variable	Model estimate	SE	P	Estimated probability of Cricetidae	AIC
<sup>c</sup> Productivity 1					24.42
<i>Low</i>	-3.2189	1.0198	<b>0.0016</b>	0.999	
<i>Medium</i>	0.2744	1.4466	0.8496		
<i>Medium</i>	-2.9444	1.0260	<b>0.0041</b>	0.999	
<i>Low</i>	-0.2745	1.4466	0.8495		
<sup>c</sup> Productivity 2					24.45
<i>Low</i>	-3.0910	1.0220	<b>0.0025</b>	0.999	
<i>Medium</i>	-0.0001	1.4460	1.0000		
<i>Medium</i>	-3.0910	1.0220	<b>0.0025</b>	0.999	
<i>Low</i>	-0.0001	1.4460	1.0000		
<sup>c</sup> Habitat type 1					22.81
<i>Bog</i>	-2.9957	1.0247	<b>0.0035</b>	0.999	
<i>Forest</i>	-0.3716	1.4438	0.7969		
<i>Forest</i>	-3.3673	1.0171	<b>0.0009</b>	1.000	
<i>Bog</i>	0.3715	1.4438	0.7969		
<sup>c</sup> Habitat type 2					22.63
<i>Bog</i>	-2.7730	1.0310	<b>0.0072</b>	0.998	
<i>Forest</i>	-0.7240	1.4470	0.6168		
<i>Forest</i>	-3.4965	1.0150	<b>0.0006</b>	1.000	
<i>Bog</i>	0.7239	1.4466	0.6168		
Habitat structure 1					23.85
<i>Open</i>	-3.4660	1.0160	<b>0.0006</b>	1.000	
<i>Medium</i>	1.0680	1.4570	0.4636		
<i>Dense</i>	-16.1000	7238.3940	0.9982		
<i>Dense</i>	-19.5700	7238.4000	0.9980	1.000	
<i>Open</i>	16.1000	7238.4000	0.9980		
<i>Medium</i>	17.1700	7238.4000	0.9980		
<i>Medium</i>	-2.3980	1.0440	<b>0.0217</b>	0.996	
<i>Dense</i>	-17.1680	7238.6980	0.9981		
<i>Open</i>	-1.0680	1.4570	0.4635		

## Appendix 1: Continued.

Explanatory variable	Model estimate	SE	P	Estimated probability of Cricetidae	AIC
Habitat structure 2					24.06
<i>Open</i>	-2.8904	1.0274	<b>0.0049</b>	0.999	
Medium	-0.2007	1.4495	0.8899		
Dense	-16.6757	5910.1154	0.9977		
<i>Dense</i>	-19.5700	5910.1300	0.9970	1.000	
Open	16.6800	5910.1300	0.9980		
Medium	16.4800	5910.1300	0.9980		
<i>Medium</i>	-3.0910	1.0225	<b>0.0025</b>	0.999	
Dense	-16.4750	5910.1255	0.9978		
Open	0.2007	1.4495	0.8899		
<sup>c</sup> Habitat structure 1					22.69
<i>Open</i>	-3.4657	1.0155	<b>0.0006</b>	1.000	
Closed	0.6325	1.4457	0.6618		
<i>Closed</i>	-2.8332	1.0290	<b>0.0059</b>	0.999	
Open	-0.6326	1.4457	0.6617		
<sup>c</sup> Habitat structure 2					22.74
<i>Open</i>	-2.8904	1.0274	<b>0.0049</b>	0.999	
Closed	-0.5437	1.4449	0.7067		
<i>Closed</i>	-3.4340	1.0160	<b>0.0007</b>	1.000	
Open	0.5436	1.4449	0.7068		
<sup>c</sup> Forest age 1					14.28
<i>Open</i>	-21.5700	18220.0000	0.9990	1.000	
Young	19.4900	18220.0000	0.9990		
Old	0.0000	22920.0000	1.0000		
<i>Old</i>	-21.5700	13910.0000	0.9990	1.000	
Open	0.0000	22920.0000	1.0000		
Young	19.4900	13910.0000	0.9990		
<i>Young</i>	-2.0790	1.0610	<b>0.0499</b>	0.992	
Old	-19.4870	13913.0280	0.9989		
Open	-19.4870	18216.9110	0.9991		
<sup>c</sup> Forest age 2					15.05
<i>Open</i>	-20.5700	13070.0000	0.9990	1.000	
Young	18.0800	13070.0000	0.9990		
Old	0.0000	15560.0000	1.0000		
<i>Old</i>	-20.5700	8439.0000	0.9980	1.000	
Open	0.0000	15560.0000	1.0000		
Young	18.0800	8439.0000	0.9980		
<i>Young</i>	-2.4850	1.0410	<b>0.0170</b>	0.997	
Old	-18.0810	8438.6790	0.9980		
Open	-18.0810	13073.5100	0.9990		

## Appendix 2:

Logistic regression models with the probability of a prey item being a cricetid as response variable, map-derived habitat variables as explanatory variables and with nest ID (5 nests) as a random variable. For all categories n = 49. Variables in italics are the intercept parameters and bold p-values significance at a 0.05 level.

Explanatory variable	Model estimate	SE	P	Estimated probability of Cricetidae	AIC
Habitat type 1					22.51
<i>Bog</i>	-2.7726	1.0308	<b>0.0072</b>	0.998	
Forest	-0.6614	1.4473	0.6477		
<i>Forest</i>	-3.4340	1.0160	<b>0.0007</b>	1.000	
Bog	0.6613	1.4473	0.6477		
Habitat type 2					22.56
<i>Bog</i>	-2.833	1.029	<b>0.0059</b>	0.999	
Forest	-0.568	1.446	0.6945		
<i>Forest</i>	-3.401	1.016	<b>0.00082</b>	1.000	
Bog	0.568	1.446	0.69456		
Soil type 1					22.64
<i>Mineral</i>	-3.3322	1.0177	<b>0.00106</b>	1.000	
Organic	0.3877	1.4451	0.78848		
<i>Organic</i>	-2.9444	1.026	<b>0.00411</b>	0.999	
Mineral	-0.3878	1.4451	0.78842		
Soil type 2					22.64
<i>Mineral</i>	-3.3322	1.0177	<b>0.00106</b>	1.000	
Organic	0.3877	1.4451	0.78848		
<i>Organic</i>	-2.9444	1.026	<b>0.00411</b>		
Mineral	-0.3878	1.4451	0.78843		
Productivity 1					23.48
<i>Impediment</i>	-3.0445	1.0235	<b>0.00293</b>	0.999	
Low	0.4055	1.4557	0.7806		
Medium	-16.5216	5118.5306	0.99742		
<i>Medium</i>	-19.57	5118.32	0.997	1.000	
Impediment	16.52	5118.32	0.997		
Low	16.93	5118.32	0.997		
<i>Low</i>	-2.6391	1.0351	<b>0.0108</b>	0.998	
Medium	-16.927	5118.3188	0.9974		
Impediment	-0.4055	1.4557	0.7806		
Productivity 2					23.88
<i>Impediment</i>	-2.8904	1.0274	<b>0.0049</b>	0.999	
Low	-0.1054	1.4511	0.9421		
Medium	-16.6758	5910.3734	0.9977		
<i>Medium</i>	-19.57	5910.13	0.997	1.000	
Impediment	16.68	5910.13	0.998		
Low	16.57	5910.13	0.998		
<i>Low</i>	-2.9957	1.0247	<b>0.00346</b>	0.999	
Medium	-16.5703	5910.125	0.99776		
Impediment	0.1053	1.4511	0.94215		

## Appendix 2: Continued

Explanatory variable	Model estimate	SE	P	Estimated probability of Cricetidae	AIC
Tree type 1					23.83
<i>Coniferous</i>	-3.2958	1.0184	<b>0.0012</b>	0.999	
Mixed	-16.2702	6701.4500	0.9981		
None	0.7308	1.4540	0.6152		
<i>None</i>	-2.5650	1.0378	<b>0.0134</b>	0.997	
Coniferous	-0.7309	1.4539	0.6152		
Mixed	-17.0012	6701.7600	0.9980		
<i>Mixed</i>	-19.5700	6701.4600	0.9980	1.000	
None	17.0000	6701.4600	0.9980		
Coniferous	16.2700	6701.4600	0.9980		
Tree type 2					24.05
<i>Coniferous</i>	-3.3322	1.0177	<b>0.0011</b>	1.000	
Mixed	-15.2339	4809.3420	0.9975		
None	0.6931	1.4516	0.6330		
<i>None</i>	-2.6391	1.0351	<b>0.0108</b>	0.998	
Coniferous	-0.6931	1.4516	0.6330		
Mixed	-15.9271	4809.5416	0.9974		
<i>Mixed</i>	-18.5700	4809.3500	0.9970	1.000	
None	15.9300	4809.3500	0.9970		
Coniferous	15.2300	4809.3500	0.9970		



### Appendix 3:

Logistic regression models with the probability of a prey item being a *Microtus* vole as response variable, observed habitat variables as explanatory variables and with nest ID (5 nests) as a random variable. For all categories n = 36, except forest age (n = 15 in habitat 1 and n = 16 in habitat 2). <sup>c</sup> denotes a compressed category; certain categories from the full model have been pooled. Categories in italics are the intercept parameters, and bold p-values denote significance at 0.05 level.

Explanatory variable	Model estimate	SE	P	Estimated probability of <i>Microtus</i>	AIC
<sup>c</sup> Productivity 1					47.38
<i>Low</i>	-1.3636	0.7264	0.0605	0.80	
Medium	0.3279	0.8621	0.7037		
High	0.3623	1.4353	0.8007		
<i>High</i>	-1.0013	1.3255	0.4500	0.73	
Low	-0.3623	1.4353	0.8010		
Medium	-0.0343	1.4191	0.9810		
<i>Medium</i>	-1.0357	0.7034	0.1410	0.74	
High	0.0342	1.4191	0.9810		
Low	-0.3279	0.8621	0.7040		
<sup>c</sup> Productivity 2					47.38
<i>Low</i>	-1.3636	0.7264	0.0605	0.80	
Medium	0.3279	0.8621	0.7037		
High	0.3623	1.4353	0.8007		
<i>High</i>	-1.0013	1.3255	0.4500	0.73	
Low	-0.3623	1.4353	0.8010		
Medium	-0.0343	1.4191	0.9810		
<i>Medium</i>	-1.0357	0.7034	0.1410	0.74	
High	0.0342	1.4191	0.9810		
Low	-0.3279	0.8621	0.7040		
<sup>c</sup> Habitat type 1					45.5
<i>Bog</i>	-1.0703	0.7373	0.1470	0.74	
Forest	-0.1512	0.8420	0.8570		
<i>Forest</i>	-1.2215	0.6216	<b>0.0494</b>	0.77	
Bog	0.1511	0.8420	0.8575		
<sup>c</sup> Habitat type 2					45.43
<i>Bog</i>	-0.9770	0.7357	0.1840	0.73	
Forest	-0.2863	0.8425	0.7340		
<i>Forest</i>	-1.2633	0.6116	<b>0.0389</b>	0.78	
Bog	0.2862	0.8425	0.7341		

### Appendix 3: Continued.

Explanatory variable	Model estimate	SE	P	Estimated probability of <i>Microtus</i>	AIC
Habitat structure 1					45.13
<i>Open</i>	-1.6012	0.8876	0.0712	0.83	
Medium	1.5924	1.0428	0.1268		
Dense	-1.0301	1.3948	0.4602		
<i>Dense</i>	-2.6310	1.4650	0.0726	0.93	
Open	1.0300	1.3950	0.4602		
Medium	2.6230	1.6370	0.1092		
<i>Medium</i>	-0.0088	1.0095	0.9930	0.50	
Dense	-2.6227	1.6375	0.1090		
Open	-1.5924	1.0428	0.1270		
Habitat structure 2					43.84
<i>Open</i>	-2.0207	0.9933	<b>0.0419</b>	0.88	
Medium	1.6434	1.0188	0.1067		
Dense	-0.3855	1.4631	0.7922		
<i>Dense</i>	-2.4062	1.3367	0.0719	0.92	
Open	0.3854	1.4631	0.7922		
Medium	2.0290	1.3850	0.1429		
<i>Medium</i>	-0.3772	0.7691	0.6240	0.59	
Dense	-2.0291	1.3851	0.1430		
Open	-1.6435	1.0188	0.1070		
<sup>c</sup> Habitat structure 1					45.24
<i>Open</i>	-1.3644	0.6552	<b>0.0373</b>	0.80	
Closed	0.4547	0.8166	0.5777		
<i>Closed</i>	-0.9096	0.7144	0.2030	0.71	
Open	-0.4548	0.8166	0.5780		
<sup>c</sup> Habitat structure 2					44.08
<i>Open</i>	-1.8936	0.8770	<b>0.0308</b>	0.87	
Closed	1.0672	0.9267	0.2495		
<i>Closed</i>	-0.8264	0.5900	0.1610	0.70	
Open	-1.0673	0.9267	0.2490		
<sup>c</sup> Forest age 1					24.95
<i>Young</i>	-0.4055	0.9129	0.6570	0.60	
Old	-0.4419	1.1443	0.6990		
<i>Old</i>	-0.8473	0.6901	0.2200	0.70	
Young	0.4418	1.1443	0.6990		
<sup>c</sup> Forest age 2					25.86
<i>Young</i>	-0.6931	0.8660	0.4230	0.67	
Old	-0.1542	1.1073	0.8890		
<i>Old</i>	-0.8473	0.6901	0.2200	0.70	
Young	0.1541	1.1073	0.8890		

## Appendix 4:

Logistic regression models with the probability of a prey item being a cricetid as response variable, map-derived habitat variables as explanatory variables and with nest ID (5 nests) as a random variable. For all categories n = 34. Variables in italics are the intercept parameters and bold p-values significance at a 0.05 level.

Explanatory variable	Model estimate	SE	P	Estimated probability of <i>Microtus</i>	AIC
Habitat type 1					42.94
<i>Bog</i>	-1.1610	0.7245	0.1090	0.76	
Forest	-0.0571	0.8642	0.9470		
<i>Forest</i>	-1.2180	0.5597	<b>0.0295</b>	0.77	
Bog	0.0570	0.8642	0.9474		
Habitat type 2					42.69
<i>Bog</i>	-1.5255	0.8326	0.0669	0.82	
Forest	0.4596	0.9316	0.6218		
<i>Forest</i>	-1.0659	0.5263	<b>0.0428</b>	0.74	
Bog	-0.4597	0.9316	0.6217		
Soil type 1					42.81
<i>Mineral</i>	-1.0825	0.5822	0.0630	0.75	
Organic	-0.3116	0.8549	0.7150		
<i>Organic</i>	-1.3940	0.7190	0.0525	0.80	
Mineral	0.3115	0.8549	0.7156		
Soil type 2					42.44
<i>Mineral</i>	-1.0002	0.5348	0.0615	0.73	
Organic	-0.6405	0.9264	0.4893		
<i>Organic</i>	-1.6407	0.8243	<b>0.0465</b>	0.84	
Mineral	0.6404	0.9264	0.4893		
Forest productivity 1					42.95
<i>Impediment</i>	-1.4525	0.7585	0.0555	0.81	
Low	0.9746	0.9385	0.2990		
Medium	-0.6771	1.3286	0.6103		
<i>Medium</i>	-2.1290	1.1650	0.0676	0.89	
Impediment	0.6770	1.3290	0.6104		
Low	1.6510	1.3120	0.2082		
<i>Low</i>	-0.4778	0.7177	0.5060	0.62	
Medium	-1.6516	1.3122	0.2080		
Impediment	-0.9747	0.9385	0.2990		
Forest productivity 2					38.8
<i>Impediment</i>	-1.5305	0.9086	0.0921	0.82	
Low	1.0989	0.9801	0.2622		
Medium	-17.0621	3802.8443	0.9964		
<i>Medium</i>	-18.5500	3719.7700	0.9960	1.00	
Impediment	17.0200	3719.7700	0.9960		
Low	18.1200	3719.7700	0.9960		
<i>Low</i>	-0.4316	0.6510	0.5070	0.61	
Medium	-18.0552	3606.9259	0.9960		

#### Appendix 4: Continued

Explanatory variable	Model estimate	SE	P	Estimated probability of <i>Microtus</i>	AIC
Tree type 1					44.6
<i>Coniferous</i>	-1.0151	0.5816	0.0809	0.73	
Mixed	-0.1741	1.3207	0.8951		
None	-0.5600	0.9754	0.5659		
<i>None</i>	-1.5750	0.8398	0.0607	0.83	
Coniferous	0.5600	0.9754	0.5659		
Mixed	0.3857	1.4175	0.7855		
<i>Mixed</i>	-1.1892	1.2065	0.3240	0.77	
None	-0.3858	1.4174	0.7850		
Coniferous	0.1741	1.3207	0.8950		
Tree type 2					43.42
<i>Coniferous</i>	-0.8787	0.5081	0.0838	0.71	
Mixed	-0.1423	1.2837	0.9118		
None	-1.3192	1.1758	0.2619		
<i>None</i>	-2.1980	1.0770	<b>0.0412</b>	0.90	
Coniferous	1.3190	1.1760	0.2619		
Mixed	1.1770	1.5820	0.4571		
<i>Mixed</i>	-1.0210	1.1880	0.3900	0.74	
None	-1.1769	1.5824	0.4570		
Coniferous	0.1422	1.2837	0.9120		

## Appendix 5:

Linear mixed effects models with  $\log_{10}$  transformed search time as response variable, and observed habitat variables and whether a delivered prey item was a *Microtus* vole as explanatory variables. Nest ID (5 nests) is included as a random variable. For all habitat variables  $n = 45$ , for the *Microtus* variable  $n = 35$ . <sup>c</sup> denotes a compressed category; certain categories from the full model were pooled. Categories in italics are the intercept parameters.

Explanatory variable	Estimate	SE	df	P	Estimated mean search time (minutes)	AIC
<sup>c</sup> Productivity 1						97.51
<i>Low</i>	1.4554	0.1279	38		28.54	
Medium	-0.1102	0.2023	38	0.5892		
High	-0.1374	0.3081	38	0.6582		
<i>High</i>	1.3180	0.2803	38		20.80	
Low	0.1374	0.3081	38	0.6582		
Medium	0.0272	0.3211	38	0.9329		
<i>Medium</i>	1.3453	0.1567	38		22.14	
High	-0.0272	0.3211	38	0.9329		
Low	0.1102	0.2023	38	0.5892		
<sup>c</sup> Productivity 2						97.84
<i>Low</i>	1.4078	0.1373	38		25.57	
Medium	0.0076	0.1992	38	0.9699		
High	-0.0897	0.3130	38	0.7759		
<i>High</i>	1.3180	0.2813	38		20.80	
Low	0.0897	0.3130	38	0.7759		
Medium	0.0973	0.3161	38	0.7599		
<i>Medium</i>	1.4153	0.1443	38		26.02	
High	-0.0973	0.3161	38	0.7599		
Low	-0.0076	0.1992	38	0.9699		
<sup>c</sup> Habitat type 1						95.13
<i>Forest</i>	1.4453	0.1216	39		27.88	
Bog	-0.1050	0.1872	39	0.5781		
<i>Bog</i>	1.3404	0.1423	39		21.90	
Forest	0.1050	0.1872	39	0.5781		
<sup>c</sup> Habitat type 2						95.24
<i>Forest</i>	1.4263	0.1154	39		26.69	
Bog	-0.0713	0.1935	39	0.7145		
<i>Bog</i>	1.3551	0.1553	39		22.65	
Forest	0.0713	0.1935	39	0.7145		

**Appendix 5: Continued.**

Explanatory variable	Estimate	SE	df	P	Estimated mean search time	AIC
Habitat structure 1						97.22
<i>Open</i>	1.3634	0.1126	38		23.09	
Medium	0.1140	0.2374	38	0.6338		
Dense	0.1334	0.3022	38	0.6613		
<i>Dense</i>						31.39
Open	-0.1334	0.3022	38	0.6613		
Medium	-0.0194	0.3497	38	0.9561		
<i>Medium</i>						30.02
Dense	0.0194	0.3497	38	0.9561		
Open	-0.1140	0.2374	38	0.6338		
Habitat structure 2						95.48
<i>Open</i>	1.2545	0.1399	38		17.97	
Medium	0.3216	0.1979	38	0.1124		
Dense	0.0686	0.2697	38	0.8007		
<i>Dense</i>						21.04
Open	-0.0686	0.2697	38	0.8007		
Medium	0.2530	0.2697	38	0.3540		
<i>Medium</i>						37.68
Dense	-0.2530	0.2697	38	0.3540		
Open	-0.3216	0.1979	38	0.1124		
<sup>c</sup> Habitat structure 1						94.95
<i>Open</i>	1.3634	0.1113	39		23.09	
Closed	0.1210	0.1996	39	0.5479		
<i>Closed</i>						30.50
Open	-0.1210	0.1996	39	0.5479		
<sup>c</sup> Habitat structure 2						93.58
<i>Open</i>	1.2545	0.1397	39		17.97	
Closed	0.2535	0.1838	39	0.1758		
<i>Closed</i>						32.21
Open	-0.2535	0.1838	39	0.1758		
<i>Microtus</i>						79.41
Yes	1.3577	0.1339	30		22.79	
No	-0.0101	0.2389	30	0.9665		
<i>No</i>						22.26
Yes	0.0101	0.2389	30	0.9665		

## Appendix 6:

Linear mixed effects models with  $\log_{10}$  transformed distance from nest as response variable, and observed habitat variables and whether a delivered prey item was a *Microtus* vole as explanatory variables. Nest ID (5 nests) is included as a random variable. For all habitat categories  $n = 56$ , for the *Microtus* variable  $n = 44$ . <sup>c</sup> denotes a compressed category; certain categories from the full model were been pooled. Variables in italics are the intercept parameters, and p-values in bold denote significant difference at 0.05 level between category and intercept parameter.

Explanatory variable	Estimate	SE	df	P	Estimated mean distance from nest	AIC
<sup>c</sup> Habitat type 1						31,77
<i>Forest</i>	2,5311	0,1074	50		339	
<i>Bog</i>	-0,1927	0,0795	50	<b>0,019</b>	217	
<sup>c</sup> Habitat type 2						35,11
<i>Forest</i>	2,4999	0,0991	50		316	
<i>Bog</i>	-0,1183	0,084	50	0,1649	240	
<sup>c</sup> Habitat structure 1						21,8
<i>Open</i>	2,343	0,1095	50		220	
<i>Closed</i>	0,3075	0,0713	50	<b>0,0001</b>	447	
<sup>c</sup> Habitat structure 2						27,21
<i>Open</i>	2,3099	0,0979	50		204	
<i>Closed</i>	0,2384	0,0721	50	<b>0,0018</b>	353	
<sup>c</sup> Productivity 1						30,12
<i>Low</i>	2,3923	0,1031	49		246	
<i>Medium</i>	0,2039	0,076	49	<b>0,01</b>	394	
<i>High</i>	-0,2065	0,1502	49	0,1753	153	
<i>High</i>	2,1857	0,1617	49			
<i>Low</i>	0,2065	0,1502	49	0,1753		
<i>Medium</i>	0,4105	0,1479	49	<b>0,0078</b>		
<sup>c</sup> Productivity 2						31,73
<i>Low</i>	2,3917	0,1029	49		246	
<i>Medium</i>	0,1778	0,0776	49	<b>0,0263</b>	371	
<i>High</i>	-0,2185	0,1529	49	0,1593	149	
<i>High</i>	2,1732	0,1612	49			
<i>Low</i>	0,2185	0,1529	49	0,1593		
<i>Medium</i>	0,3963	0,1499	49	<b>0,011</b>		
Habitat structure 1						25,8
<i>Open</i>	2,3396	0,1121	49		218	
<i>Medium</i>	0,2961	0,0841	49	<b>0,0009</b>	432	
<i>Dense</i>	0,3344	0,1218	49	<b>0,0084</b>	472	
<i>Dense</i>	2,674	0,1453	49			
<i>Open</i>	-0,3344	0,1218	49	<b>0,0084</b>		
<i>Medium</i>	-0,0383	0,1419	49	0,7882		
Habitat structure 2						30,7
<i>Open</i>	2,3014	0,0998	49		200	
<i>Medium</i>	0,212	0,0759	49	<b>0,0074</b>	326	
<i>Dense</i>	0,3266	0,1088	49	<b>0,0042</b>	424	
<i>Dense</i>	2,628	0,1171	49			
<i>Open</i>	-0,3266	0,1088	49	<b>0,0042</b>		
<i>Medium</i>	-0,1146	0,1061	49	0,2852		
<i>Microtus</i>						49,27
<i>Yes</i>	2,6372	0,1516	38		433	
<i>No</i>	0,0275	0,1249	38	0,827	462	

## Appendix 7: Field registration forms and explanations

### Explanation to field checklist

- **Date:** E.g. 10.06.11.
- **Time:** E.g. 12:34.
- **Frequency:** Radio frequency (MHz).
- **Locality:** Location name at the specific nest-box. (Example: Ørsjøsetra).
- **Sex:** Male (M) or female (F).
- **Obs.:** Initials of the observer.
- **Temp.:** °C. Measured at the site within 30 minutes.
- **Wind:** Scale from 1 to 4, (1=calm, 2=moderate, 3=strong wind, 4=very strong wind).
- **Cloud cover:** Scale from 1 to 3, (1=clear, 2=partly clouded, 3=overcast).
- Precipitation: Yes/no.
- **UTM:** UTM-coordinates at the specific location.
- **Behavior:** Perching (P), hovering (H), or flight (F).
- **Detailed comment on behaviour:** For example if it is perching, hunting, or preening?  
If it is hunting, does it catch a prey species?
- **Perch:** What kind of structure does the kestrel perch on.
- **Absolute height:** The bird's absolute height above ground, in meters (m).
- **Relative height:** The bird's height relative to its perch, (0.0=ground, 1.0=treetop).
- **Fright distance:** Distance between the observer and the bird when the bird flies off due to the observer (measured by pacing).
- **Habitat type:** Categories to be derived from electronic forestry maps. (E.g. spruce forest, pine forest, bog.)
- **Dominant tree:** Pine (P), Spruce (S) or Birch (B).
- **Forest height:** Maximum height of the forest canopy above ground (m).
- **Age:** Forest age, ranging from 1 (clear cut) to 5 (pristine forest).
- **Structure:** Forest structure: Open (O), medium (M) or dense (D).
- **Distance to open habitat:** Distance in meters (m) to open habitat: Bog (B), clearcut (CC), field (F) with specification of type of habitat.
- **Distance to closed habitat:** Distance to forest, with specification of forest type.
- **Managed/Natural forest:** If the site is in a managed forest, or natural forest.
- **Comments:** Relevant comments, for instance uncertainties with the registrations, etc



Obs. no.	Date	Time	Freq.	Locality	Sex	Observer	Temp.	Wind	Cloud cover	Precipitation	UTM	Behavior	Detailed comment on behavior
	10.06.11	12:34	123		F,M	NN	°C	1-4	1-3	Y/N		P,H,F	
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2													
3													
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5													
6													
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First sheet of checklist to be used in the field when evaluating the kestrel's habitat

Obs. no.	Time	Perch	Abs.height	Rel.height	Fright dist.	HABITAT							Comments	
						Habitat type	Domin tree	Forest height	Age	Struct	Dist to open hab.	Dist to closed hab.		Managed/ Natural
	12:34	Type	m	0.0-1.0	m.		S,P,B	m	1-5	O,M,D	m /type	m /type	M/N	
1														
2														
3														
4														
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