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Temporal patterns of main and alternative prey deliveries at a Eurasian kestrel (*Falco tinnunculus*) nest

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Abstract

Prey switching is an important part of predator feeding and breeding ecology since prey populations and therefore prey availability is dynamic. Deliveries of prey made by the Eurasian kestrel (Falco tinnunculus) breeding in a nest box in southern Norway, were recorded with a camera. Temporal activity of ground dwelling prey was recorded using five Reconyx cameras mounted in tunnel shaped boxes. Both were analysed in terms of temporal overlap. Total observations made of nest deliveries and camera traps, respectively were: 383 and 80 of Shrews (*Sorex spp.*), 190 and 6 of lemmings (*Lemmus lemmus*), 102 and 53 of the bank vole (*Myodes glareolus*), 60 and 64 *Microtus* voles (*Microtus* spp.) and 20 deliveries of birds to the nest. Shrews, *Microtus* voles and the bank vole were defined as the main prey and birds as an alternative prey. The main prey species had similar, but varying temporal patterns of activity and deliveries. The kestrel increased deliveries of birds (their alternative prey) when deliveries of main prey were decreasing in the hours between 11:00 and 18:00, the decrease in main prey deliveries around this time was small, and bird deliveries in these hours were probably an additive energy source. The kestrels deliveries of alternative prey did therefore follow a consistent hourly trend. Our results are similar with other findings made of Norwegian breeding kestrels by Steen et al., (2011a), where the same patterns of alternative prey deliveries occurred, around the same timeframe as our results, but with another alternative prey, the viviparous lizards (*Zootoca vivipara*). This consistent temporal change in prey composition, where alternative prey was commonly delivered for a brief period, should increase the prey mass delivered to the nestlings, and create a more stable feeding pattern throughout the day. The switch to an increase of bird being delivered at the nest were a discreet, but rapid form of prey switching. This thesis is to my knowledge the only study using this methodology to determine hourly changes in prey composition for a predator.

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Introduction

Species ecological niches have been the subject for ecological research for over a century (Grinnell, 1917, Elton, 2001). The ecological niche of a species can be defined as a range, where the species are adapted in terms of e.g. temperature and diet (Futuyma and Moreno, 1988). The most studied form species niche is geographical ranges where the species niche is described as the spatial habitat it inhabits (Soberón, 2007, Pulliam, 2000). Another principle niche variable is the diet of a species (Svanbäck and Persson, 2004, Machovsky-Capuska et al., 2016). Time as a niche variable, or temporal niche, is also an important ecological aspect. Because animals have different activity and distribution patterns during the 24 hours of the day (Hut et al., 2012). Temporal partitioning can occur as a result of both inter and intraspecific competition for resources (Valeix et al., 2007), as vell as predation (Cunningham et al., 2019). Temporal partitioning may facilitate coexistence between predators and prey, utilising the same spatial habitat at different times of the day (Kronfeld-Schor and Dayan, 2003).

Predation is a complex ecological interaction, that highly influences species adaptation and evolution (Vermeij, 1982). For predation to occur there are several steps that must happen in a chronological order that involves the predator and prey. Both predator and prey must share their spatiotemporal location, the predator needs to encounter the prey, the predator must attack prey and be successful in killing/consuming the prey species (Lima and Dill, 1990). The predation sequence can end at any of the previous points, making predation a complex ecological interaction (Suraci et al., 2022).

Predator prey interactions have been an important part of ecological and evolutionary sciences. One factor that affects these interactions is whether the predator is a specialist or a generalist in terms of diet. Specialist predators are predators that only prey on a small selection on prey, and are therefore highly adapted to hunting these prey species (Hanski et al., 1991). For specialist predators, biomass intake will vary with the current abundance of their preferred prey species (Terraube et al., 2011). Generalist predators usually favour certain prey item more than other ones, but do more easily adapt to low abundance of those particular prey items (Reid et al., 1997). The alternative prey hypothesis (APH) describes numeric changes in predators in relation to their preferred prey densities, where increase in predators leads to an increase in predation on preferred prey species. Which in turn can lead to a reduction of preferred prey availability, and heightens the predation pressure on alternative prey (Kjellander and Nordström, 2003, Sonerud, 2022). APH implies a switching of prey species that occurs on a longer temporal scale, such as annual changes in prey species densities (Korpimäki et al., 1990).

Prey switching describes changes in a predators prey selections, in relation to what is most abundant or available at any given time (Tschanz et al., 2007). Prey switching on a shorter time frame is not uncommon, and predator diet can change seasonally because of changes in ground cover, making some prey unavailable (Nybo and Sonerud, 1990). The seasonal changes in a generalist predators diet, could also be a result of seasonal changes in prey species abundance (Tome, 1994, Moorhouse-Gann et al., 2020). Daily prey switching can occur in seabirds such as the Scopoli's shearwaters (*Calonectris diomedea*), where the marine prey populations are highly dynamic (Courbin et al., 2018).

Steen et al., (2011a) found changes in the daily temporal pattern of alternative prey species being delivered to nestlings in the Eurasian kestrel (*Falco tinnunculus*), from now on called the kestrel. The likelihood of the alternative prey, viviparous lizard (*Zootoca vivipara*) being delivered at the nest, where higher in the hours around noon. Lizard deliveries were highly linked with ambient temperature, and lizards should therefore be more active around the times when they were frequently delivered. This kind of prey switching were on a short temporal scale but were not a binary switch since the kestrel still delivered other kinds of prey around these hours as well.

According to optimal foraging theory (OFT), predators should forage prey that leads to maximum calorie intake for the time used to hunt and handle prey, predators should therefore focus their efforts on the most profitable prey items if they are abundant (Sih and Christensen, 2001). Prey switching is one way for predators to optimize their energy intake, in accordance with OFT (Křivan, 1996). If high quality energy dense prey items are scarce, prey switching may be one way to meet the energy needs of the predator. If the alternative prey consumed are of low profitability this could impact the predators body condition (Moorhouse-Gann et al., 2020). In the lesser kestrel (*Falco naumanni*), breeding pairs that had smaller portion of their preferred prey in their diet, had lower reproductive success (Rodríguez et al., 2010).

Recent methods in studying temporal overlap of species activity, have been using wildlife cameras to observe different species as the same geographical site, but at different times of the day. This is a method that has been used frequently in recent times, to study differences in spatiotemporal activity for predator and their prey species (Havmøller et al., 2020, Linkie and Ridout, 2011, Azevedo et al., 2018). Using camera traps to sample both predator and prey in the same special habitat, does not necessarily increase knowledge about actual predation incidents, but increases knowledge about some aspects of predator and prey spatiotemporal interactions. The earlier studies that used this kind of methodology usually studied mammalian prey, where direct predation incidents may be cryptic and difficult to record.

The aim of this thesis was to study the temporal relationship between prey deliveries at the nest of a Eurasian kestrel (*Falco tinnunculus*) pair, and the temporal activity of its prey species on the kestrel hunting grounds. The other aim of this thesis was to study the temporal patterns of deliveries of the different prey species, on an hourly scale. The kestrel diet is that of a generalist, and there is usually alternative prey in varying numbers in their diet (Hagen, 1952, Korpimäki, 1985a, Steen et al., 2011b). Does the kestrel switch between prey species at different times of the day, and does alternative prey selection follow a consistent hourly trend?

Methods

Study site and duration

The study area was located the municipality of Tinn in Telemark Norway (Figure 1). The Eurasian kestrel nested in a box located on the wall of the building for the national park visitors' centre. The box was located 5-6 m above ground, on a site of the building that was not exposed to tourist traffic. The location was approximately 1000 m above sea level. The vegetation in the area surrounding the nest box is a mixture of coniferous forest and mountainous shrub vegetation. The camera traps for recording small mammal prey activity were located in an area dominated by shrub vegetation. The five camera traps were in proximity of the nest box, with the one furthest away at around 1000m from the nest box (Figure 1).

The field work was conducted in the summer 2021. The video recording at the nest started June 22nd, when the kestrel nestlings were approximately 10-12 days old, and continued until July 3rd. In total, 11 full days of video recordings at the nest. The camera trap photo recording of ground dwelling prey species was done between May and August 2021 to analyse prey activity in the study area.

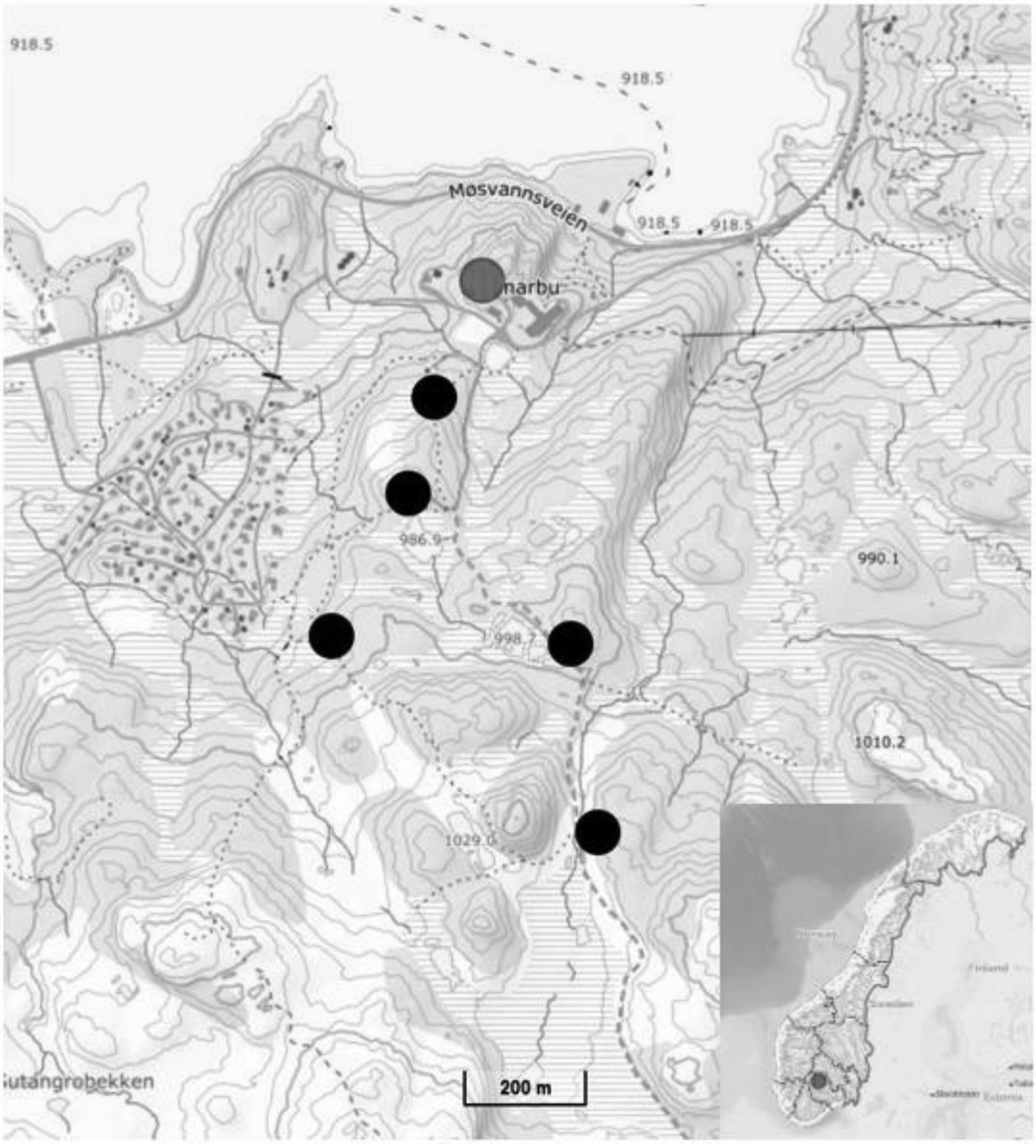

FIGURE 1 MAP OF THE STUDY AREA. THE RED DOT DENOTES THE LOCATION OF THE KESTREL NEST BOX, AND EACH BLACK DOT DENOTES THE LOCATION OF ONE CAMERA TRAP. THE SCALE OF THE MAP IS 1:50000. (KARTVERKET, 2022).

Study species

The Eurasian kestrel is a medium-sized predatory bird. The most common prey item for the kestrel in Fennoscandia are small mammals and rodents. This includes *Microtus* voles and the bank vole (*Myodes glareoulus*), Birds and shrews (*sorex* ssp.) as well as some viviparous lizards (*Zootoca vivipara*), and usually low numbers of insects and frogs (Korpimäki, 1986, Steen et al., 2011b, Montoya et al., 2021). During the breeding season there seems to be an increase in proportion of shrews in the diet (Korpimäki, 1985a, Steen et al., 2012). Norway lemming (*Lemmus lemmus*), from now on referred to as lemming, are a relatively rare prey item for the kestrel (Hagen, 1952, Støvern, 2012). The kestrel diet will vary in accordance with available prey. If shrews and voles are scarce, birds may make up a large proportion of the diet (Kreiderits et al., 2016). The kestrels preferred prey items are often nocturnal and crepuscular as is the case for the bank vole (Greenwood, 1978), as well as for shrews (Rychlik, 2005), *Microtus* voles also show decreased activity at daytime, especially during summer (Hoogenboom et al., 1984).

Photo and video recording

Ground dwelling prey species were recorded using five camera traps each placed in a tunnel-shaped wooden boxes. The camera trap used were Reconyx RC900hyperfire, that took three pictures when animals moved through the box and triggered the camera sensor. The flash used in these camera traps are infrared and make minimal disturbance. The nest monitoring were done using a small surveillance camera mounted inside the nest box, similar to that used by Steen (2009), but the recording system in our case were connected to the power grid, and the camera were connected to a computer, where the recordings where saved.

Data analyses

The data processing was at first done manually by reviewing the recorded videos from the nest box. To categorise and analyse the video material of prey delivered at the nest, the Boris software (Friard and Gamba, 2016) was used. This software made it possible to combine information about what kind of prey species that were being delivered, and time of delivery. Prey delivered at the nest, where only counted if it was eaten by the nestlings. This excluded some deliveries where the male kestrel entered the nest box with prey but left with the prey before any of the nestlings had a chance of eating it.

The camera trap pictures were first sorted manually to species or family/subgroup. After this the R software (R Development Core Team, 2013) was used with a custom made script, that utilised exiftool.exe (https://exiftool.org/) to gather information such as time and date from the sorted pictures. To reduce the possibility of pseudo observations, there were used a 30 minute delay for observations of the same species in the same camera trap box, similar to the delay described by Havmøller et al,. (2020).

The data of both prey activity and prey deliveries were analysed in the R software. To create the activity plots for each of the prey species the R package 'Activity' v. 1.3.1 (Rowcliffe and Rowcliffe, 2016) were used. To analyse temporal overlap between prey species activity and prey deliver at the nest, the R package 'Overlap' v. 0.3.4 (Meredith and Ridout, 2014) was used. The time for each observation were converted from a normal linear time format to radians to utilize the 'Overlap' and 'Activity' package. This converted time to circular value, which were needed since observations made before midnight and straight after were closely related in time, which would not happen if time was linear.

For sample sizes larger than n=75 the estimator Δ_4 were used as an estimator for calculating the overlap coefficient, and for smaller sample sizes the estimator Δ_1 were used (Ridout and Linkie, 2009). The coefficient of overlap Δ is a nonparametric descriptive variable for temporal overlap between two different kernel density curves (Ridout and Linkie, 2009). Where Δ=0 is no temporal overlap, and Δ=1 is a complete temporal overlap between pairs of variables (Frey et al., 2017). Coefficient of overlap values of Δ <0.5 were defined as low temporal overlap, values between 0.5 and 0.75 as moderate temporal overlap and values >0.75 as high degree of temporal overlap between compared variables, as proposed by Monterroso et al,. (2014). Bootstrapping for the estimated 95% confidence intervals for Δ, was done using the function overlapEst in package 'Overlap' V.0.3.4. The bootstrap was performed 10 000 times for each pair of variables (Meredith and Ridout, 2016). For statistical testing the Mardia-Watson-Wheller (Batschelet, 1981) test, were used since this test is suitable for circular variables. It was used to test if the activity curves for kestrel deliveries and prey overlap curves were significantly different. This test where also used to test for a significant difference between the overlap curves of different prey deliveries, method as described by Durán-Antonio et al., (2020) and Tasdan and Yeniay (2014).

Results

The camera traps at the study site revealed 846 individual observations of potential small mammalian prey. Shrews were most frequent, followed by lemmings, bank voles and *Microtus* voles, supplemented by a few lizard observations (Table 1). The camera at the nest box recorded 255 deliveries of prey that were consumed by either the nestlings or by the female kestrel, in combination with the nestlings. For deliveries, the most common prey were shrews, *Microtus* voles and bank voles, with fewer observed deliveries of birds, lemmings, and lizards (Table 1). Given that the majority of delivered prey were shrews, *Microtus* voles and bank vole, these were defined as the kestrels main prey in this thesis. These taxa and specie will be referred to as the main prey species hereafter. Lemmings were not a part of the overlap analysis due to low number of deliveries, making them unsuitable for analysis. A total of 20 birds were delivered at the nest (Table 1). These were from at least four species, with varying size, but birds are treated as functionally the same prey species hereafter.

TABLE 1 NUMBER OF OBSERVATIONS OF DIFFERENT PREY SPECIES OBSERVATIONS AMONG DELIVERIES AT THE NEST BOX AND AMONG RECORDS MADE BY CAMERA TRAPS AT THE STUDY SITE, COMBINED FOR ALL FIVE CAMERAS.

Species name	Common name	Camera trap	Nest box
Sorex Species	Shrew	383	80
Microtus Species	Microtus voles	60	64
Myodes glareolus	Bank vole	102	53
Lemmus lemmus	Lemming	190	6
Zootoca vivipara	Viviparous lizard	8	4
Turdus species	Thrush sp.	NA	5
Turdus philomelos	Song thrush*	NA	1
Turdus pilaris	Fieldfare	NA	4
Lagopus species	Ptarmigan chick	NA	1
	Unknown small bird	NA	6
Periparus ater	Coaltit*	NA	1
	Unknown bird	NA	2
Apodemus flavicollis	Yellow-necked mouse*	NA	2
	Small mammal unknown	70	8
	Rodent unknown	26	2
	Unknown	7	16
Total		846	255

*Probably

Activity of prey species and prey deliveries

Microtus voles, bank vole and shrews had similar temporal activity patterns, with a decrease in observations of these during daytime (Figure 2). For all the main prey species, *Microtus* voles, bank vole and shrews, the activity decreased already before sunrise, and their activity started to increase some hours before dusk (Figure 2). In contrast, lemmings were mainly diurnal, with a bimodal activity pattern with a decrease in activity midday (Figure 2). Kestrel prey deliveries happened mainly during the day, with some differences in when different species were delivered during the day, and some prey deliveries happened around dusk and dawn (Figure 2). There were no deliveries in the timeframe from midnight to 03.00, when the female kestrel would stay in the nest box with the nestlings.

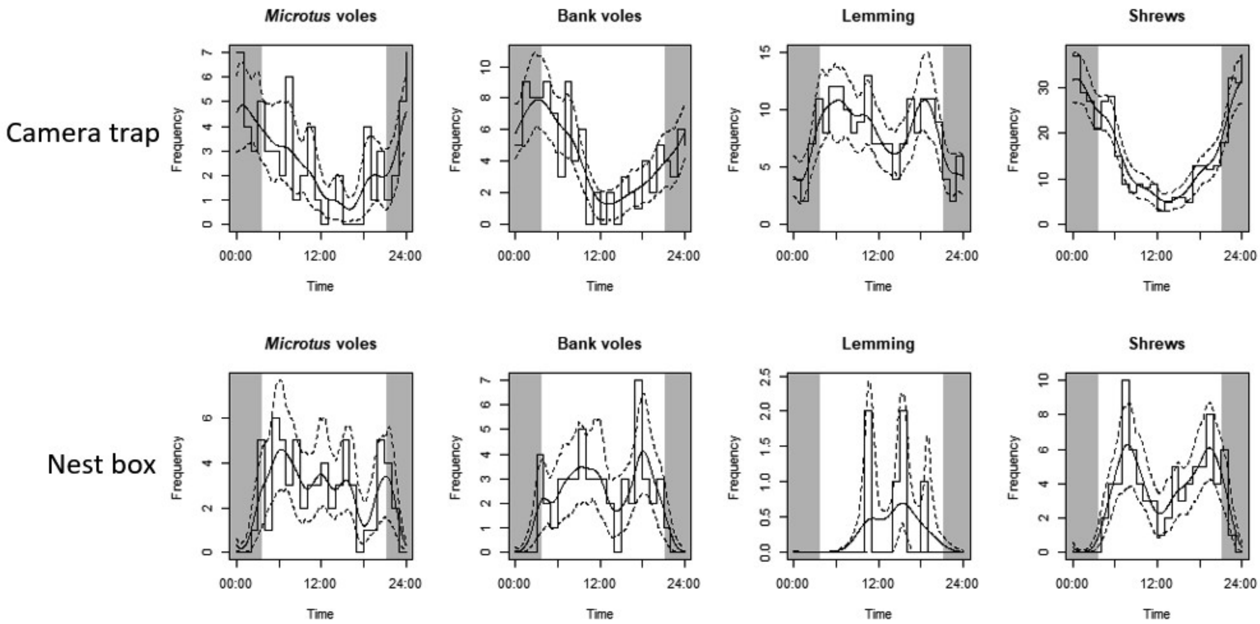

FIGURE 2 TEMPORAL PATTERNS FOR PREY SPECIES ACTIVITY AND PREY DELIVERIES MADE AT THE KESTREL NEST. THE FOUR TOP PLOTS SHOW PREY SPECIES ACTIVITY IN THE FIELD, AND THE BOTTOM FOUR PLOTS SHOW TEMPORAL PATTERNS FOR DELIVERIES OF THESE SPECIES AT THE KESTREL NEST BOX. ACTIVITY IS SHOWN AS FREQUENCY OF OBSERVATIONS MADE BY CAMERA TRAPS FOR TOP PLOTS, AND FREQUENCY OF DELIVERIES FOR BOTTOM PLOTS. THE GREY FIELD IN THE PLOTS ARE FOR HOURS WHEN THE SUN IS SET, AS AN AVERAGE FOR THE PERIOD THE CAMERA TRAP WERE ACTIVE.

Temporal overlap between prey activity and deliveries

There was some degree of overlap between kestrel deliveries of prey and activity patterns of the same prey for all the main prey species (Figure 3). Kestrel deliveries and prey activities for the same species display a high degree of overlap around 06:00 and 22:00 (Figure 3). Kestrel deliveries decreased in varying degree with prey activity during the day for all main prey species (Figure 3).

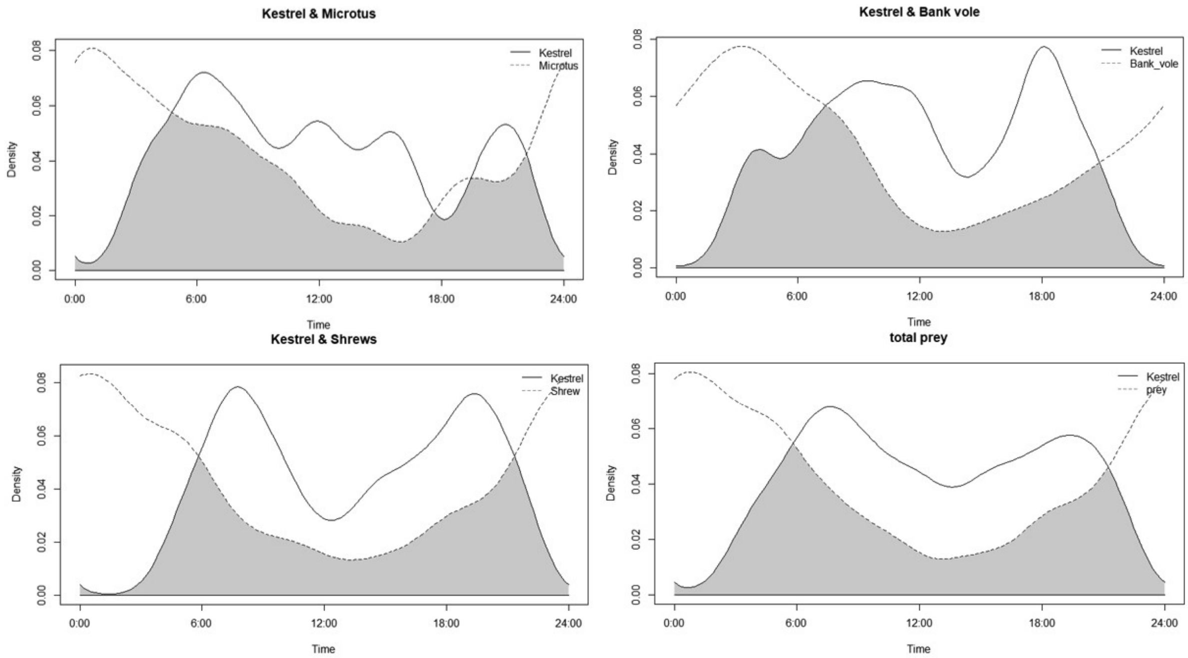

FIGURE 3 TEMPORAL OVERLAP PLOTS FOR MAIN PREY SPECIES ACTIVITY IN THE FIELD VS KESTREL PREY DELIVERIES MADE OF THE SAME SPECIES. TOTAL PREY DISPLAY THE THREE MAIN PREY SPECIES STUDY AREA ACTIVITY COMBINED VS DELIVERIES MADE OF THESE.

The three main prey species displayed moderate coefficient of overlap between activity and kestrel deliveries at the nest for the same species (Table 2). Of these species *Microtus* voles had the highest degree of temporal overlap between activity and deliveries by the kestrel (Table 2). The temporal overlap between main prey species activity and deliveries, was the lowest for shrews. There were significant differences between the main prey overlap curves and the overlap curves for prey species deliveries, which means that these are not synchronised (Table 2). Total predation of the main prey species follows the dip in prey activity around noon (Figure 3). The temporal overlap was highest in the early morning when prey activity was decreasing and deliveries were increasing, the opposite was seen at nighttime (Figure 3). The coefficient of overlap was moderate, and the overlap curves were significantly different for combination of main prey and their deliveries (Table 2).

TABLE 2 COEFFICIENT OF OVERLAP AND BOOTSTRAP VALUES FOR EACH OF THE MAIN PREY DELIVERIES MADE AT THE NEST VS MAIN PREY SPECIES ACTIVITY IN THE STUDY AREA. TOTAL MAIN PREY, ARE THE ANALYSIS OF MAIN PREY SPECIES COMBINED VS THEIR COMBINED STUDY AREA ACTIVITY.

Prey species	Coefficient of overlap (Δ)	Bootstrap mean (10 000)	CI	P
Microtus voles	0.660	0.677	0.530-0.780	0.0020
Bank vole	0.600	0.603	0.472-0.733	<0.001
Shrew	0.533	0.572	0.454-0.610	<0.001
Total main prey	0.600	0.626	0.540-0.659	<0.001

Temporal overlap between main and alternative prey deliveries

The overlap plots comparing bird deliveries to deliveries made of each of the main prey species, display moderate overlap between these (Figure 4). Birds were delivered mainly between 11:00 and 18:00. The overlap curve for delivered birds display a shorter but higher peak in density, than for the main prey, in this short timeframe (Figure 4). In the hours when bird deliveries were most common, there was a decrease in deliveries of the main prey species. (Figure 4). Both shrews and *Microtus* voles deliveries peaked when bird deliveries were declining, for bank voles the later peak in density happened earlier and bird deliveries had some overlap with both peaks in bank vole deliveries (Figure 4). Comparing bird deliveries with the main prey deliveries combined displays the peak in bird deliveries, when deliveries of the main prey reached a low spot in numbers of deliveries (Figure 4).

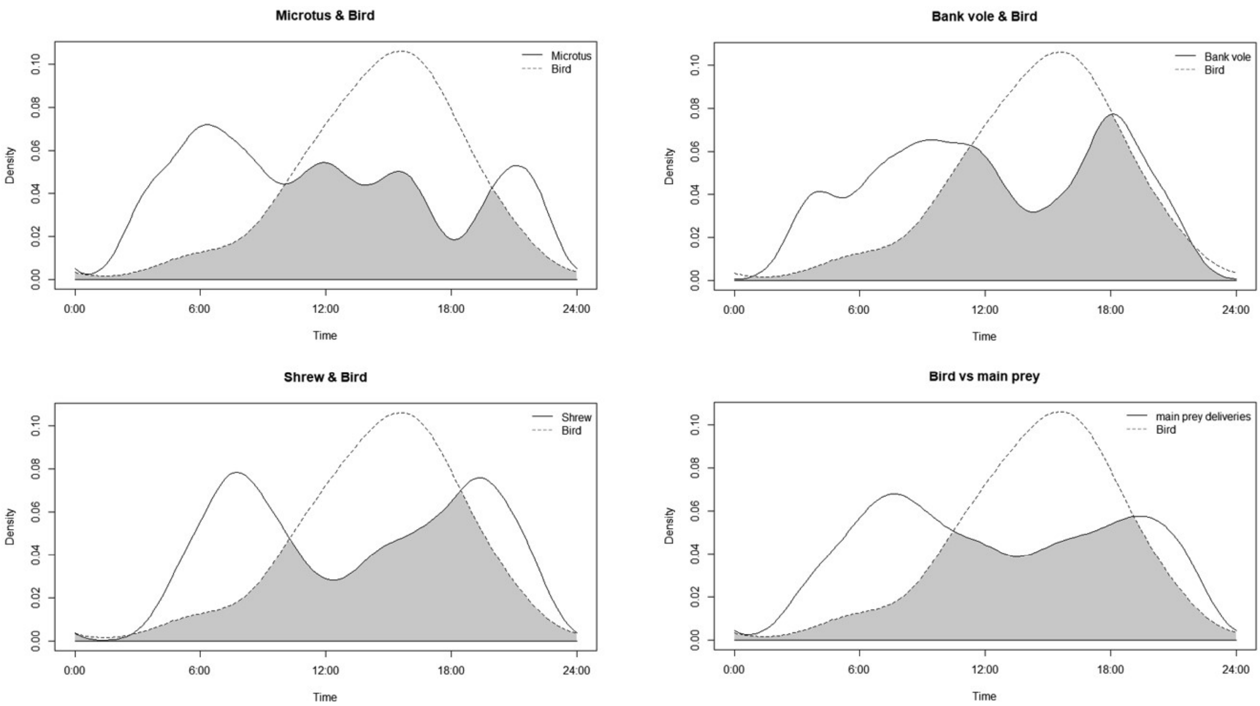

FIGURE 4 OVERLAP PLOTS FOR BIRD DELIVERIES VS DELIVERIES FOR EACH OF THE MAIN PREY. BIRDS VS MAIN PREY PLOTS BIRD DELIVERIES VS THE COMBINED DELIVERIES OF THE THREE MAIN PREY SPECIES.

The coefficient of overlap revealed that there was moderate temporal overlap between bird deliveries, when compared to each of the main prey species (Table 3). Additionally, there were moderate temporal overlap between bird deliveries, and the combined deliveries made of the main prey species (Table 3). There was significant difference between all pairs of variables compared in the overlap analysis, meaning none of the overlap curves were synchronized (Table 3).

TABLE 3 COEFFICIENT OF OVERLAP AND BOOTSTRAP VALUES FOR MAIN PREY DELIVERIES MADE ONTO THE NEST VS BIRD DELIVERIES FOR EACH MAIN PREY SPECIES. BIRD VS MAIN PREY ARE THE OVERLAP ANALYSIS FOR A COMBINATION OF DELIVERIES OF MAIN PREY AS ONE VARIABLE AND BIRD DELIVERIES.

Prey species	Coefficient of overlap (Δ)	Bootstrap mean (10 000)	CI	P
Bird vs Microtus vole	0.593	0.600	0.423-0.762	0.0018
Bird vs Bank vole	0.689	0.663	0.517-0.848	0.0026
Bird vs Shrew	0.632	0.648	0.463-0.788	0.0018
Bird vs main prey	0.649	0.657	0.496-0.798	<0.001

Discussion

Temporal relationship main prey species

The kestrel most often arrived at the nest with a *Microtus* vole, a bank vole, or a shrew, more rarely with a bird, a lizard, or a lemming. This is similar, but with a higher number of shrews than previously found in the breeding kestrel diet in Norway (Steen et al., 2011b). Finnish breeding kestrels, showed a clear annual variation in diet composition, and in some years shrews could be as common in the diet as voles (Korpimäki, 1985b). Studies from non-breeding kestrels have found more voles and less shrews in their diet (Masman et al., 1988), but kestrel diet varies in accordance with the habitat the kestrels are hunting (Village, 1990). The kestrel diet is that of a true generalist, and even though they show a clear preference for voles, they usually have some alternative prey species in their diet (Hagen, 1952, Korpimäki, 1985a, Støvern, 2012).

The recorded activities in the study area, were lower for bank vole and *Microtus* voles than for both shrew and lemmings, which could indicate lower densities. One key factor that determines kestrel diet is the availability of voles (Korpimaki and Norrdahl, 1991). The high portion of shrews in the breeding diet could be a result of kestrel nestlings being able to eat small prey items alone sooner (Steen et al., 2010). Lemming activity was high in the study area, but there are almost no deliveries made of this species to the nest. The low portion of delivered lemmings are in accordance with findings made by Hagen (1952) and Støvern (2012).

Camera trap data of the ground dwelling main prey species gave information about frequency of their temporal activity, but not species population densities. The species activity does not correlate directly with prey availability, since this is influenced by factors such as; ground cover (Nybo and Sonerud, 1990), temperature (Adams et al., 1982) as well as prey size and abundance (Griffiths, 1975).

The kestrel prey deliveries displayed a moderate temporal overlap with the activity of the main prey species in the area. The activity patterns for the kestrel deliveries were in accordance with earlier finding, as the kestrel is known to be diurnal (Village, 1990). The moderate overlap between kestrel deliveries and prey activity is to be expected since these are known prey species. Therefore, the findings fit with the expectations that there would be some degree of overlap between kestrel deliveries and activity for the same prey species. *Falco* species in previous research show a high hunting pressure in the midday (Lang et al., 2019). Therefore, even though there were low observed activity midday for the main prey species, the availability of these species as prey must be somewhat sufficient since these after all are the kestrels main prey. The overlap plot for total prey, showing combinations of main prey activities versus main prey deliveries, show a striking similarity with the overlap graph for shrew activity and deliveries (Figure 3). This is probably a result of shrew being the most common prey item.

Temporal patterns for alternative prey deliveries

The relatively small proportion of birds among prey being delivered as the kestrel nest, was as expected, since birds make up a regular but usually small portion of the kestrel diet (Van Zyl, 1994, Riegert et al., 2009, Steen et al., 2011b). Birds deliveries had a moderate coefficient of overlap with deliveries made of each main prey species in this study. This is in accordance with expectations, considering that it is the same diurnal predator that is delivering both prey groups.

Bird deliveries happened in a shorter time frame than the main prey deliveries and occurred when there are fewer deliveries of the main prey. Passerine bird species seems to be active from before sunrise until after dusk (Byrkjedal et al., 2012). Therefore, a higher number of bird deliveries made around noon and a few hours afterwards may not correlate with higher birds availability at these times. The increase in bird deliveries made during these hours may instead suggest a switch from main prey species to birds, due to lower availability of the preferred prey species at these times. This happened although main prey deliveries still occurred, and deliveries of main prey only decreased slightly during the times when bird deliveries were most common (Figure 4). Therefore, the temporal diet differentiation is a discreet, but consistent pattern throughout the study period. Birds may act as a dietary supplementation correlating with the small daily drop in main prey deliveries. On the longer seasonal or annual scale, birds are alternative prey for kestrels when voles and shrews are scarce (Kreiderits et al., 2016). Deliveries of birds should be unaffected by nestling age (Steen et al., 2012).

This thesis appears to be the first research that is determining prey switching on an hourly scale, utilizing the 'Overlap' method. The results are similar to findings of other studied Norwegian breeding kestrels. Where the alternative kestrel prey were lizards, which were delivered in relatively high numbers during that research. The lizards was more likely to be delivered around noon than the main prey species, following daily temperature fluctuations (Steen et al., 2011a). Alternative prey being delivered in higher frequency in the hours around noon, are similar between results from this thesis and the mentioned article. The drivers for the discrete daily prey switch were probably affected by main prey availability in these hours, combined with a low degree of satiation of growing nestlings (Korpimäki, 1986). The results from this thesis, were from the period where the kestrel nestlings had their highest energy needs, and was in the period when they receive the most prey items (Steen et al., 2012). This might lead to a situation where the kestrel could be less specific about what kind of prey it delivers, if the energy needs of the growing nestlings are met. As mentioned earlier, the kestrels usually have some alternative prey in their diet. Therefore, it could be the case that the temporal relationship between alternative and main prey species, seen in this thesis, is a relatively normal part of kestrel feeding ecology.

Further research should utilize technology such smart image processing and artificial intelligence, for determining deliveries made by the kestrel, and for sorting the camera trap images. This would be more time efficient and would lessen the time used for manually assessing these recording and images.

Conclusion

The results from this thesis display breeding kestrels delivering alternative prey in a consistent hourly trend. The kestrels main alternative prey was found to be birds, most of which were being delivered between 11:00 and 18:00. Bird deliveries had a steep spike in frequency in a relatively short timeframe around midday, when main prey deliveries were decreasing. Hence the kestrel may switch to the alternative avian prey during this time of the day, due to less availability of main prey. Alternative prey being delivered in greater numbers around certain time intervals, is in accordance with findings made by Steen et al., (2011a). In that article daily discrete prey switching around noon were found for the alternative prey, lizards. Prey switching to alternative prey for parts of the day, could be an important part of kestrel breeding, considering that the kestrel usually has some portion of alternative prey in their diet. Further researching the hourly trends in deliveries made of breeding kestrels, would allow comparison of these results, with a situation where the prey composition is different. This would be helpful in determining if the patterns found in this thesis were stochastic or part of the kestrel feeding behaviour. Further research using the 'overlap' methodology on prey deliveries could lead to new insight into the temporal prey selection of both generalist and specialist predators on the scale of hours.

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