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# Rise of the Eagle Owl population due to rat-rich refuse dump sites and fall when closing them: a large-scale long-term "supplementary feeding experiment"

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Food-supplementation experiments conducted on terrestrial vertebrates have usually shown the importance of food as an agent in increasing reproductive success. However, to date, the number of large-scale food supplementation experiments carried out on top predators has been limited. The Eurasian Eagle Owl (*Bubo bubo*) is the largest nocturnal avian predator in the boreal and temperate regions of Eurasia. Here, we study the diet composition and breeding success of this top predator in relation to the location and distance to rubbish dumps, which sustain large numbers of brown rats *Rattus norvegicus*, one of the main prey items for owls. The number of these rubbish dumps (hereafter dumps) increased in Finland during the period between the 1960s and the 1990s, whereafter their number was steeply reduced, leading to a remarkable decline in rat populations. A similar trend in the Eagle Owl population largely followed this development, raising the question of whether this country-wide "supplementary feeding experiment" was behind this phenomenon. The proportion of rats in the diet of the owls was high, on average, 70% of prey items near the dumps decreasing to around 10–15% at a 6–7 km distance from the dumps. Correspondingly, the number of 3–4-week-old offspring declined in relation to the distance from the dump, so that 0.5 less chicks were recorded at a distance of 10 km from the dump. During the study, the overall density of nests near the dumps was 2.7 times higher than those recorded further away. The availability of extra food material within the dumps (and rats therein) probably induced an increase in the Finnish Eagle Owl population, which saw a decline after dumps were closed.

## 1. Introduction

Food-supplementation experiments conducted in terrestrial vertebrates have usually shown the importance of food as an agent to advance a breeding season, increase clutch or litter size and improve reproductive success (Boutin 1990, Ruffino *et al*. 2014). The positive effect of food supplements was usually highest during the seasonal scarcity of food resources and showed that many animal populations were food-limited (Boutin 1990, Newton 1998, 2002, Ruffino *et al*. 2014). However, a vast majority of food-supplementation experiments have been conducted with small mammals, herbivorous and insectivorous birds as well as with small or medium-sized predators, while food-addition experiments, showing food limitation in populations of top predators, have remained scarce (but see Ward & Kennedy 1996, Kennedy & Ward 2003, McKinnon *et al*. 2024).

The Eurasian Eagle Owl *Bubo bubo* (hereafter Eagle Owl) is the largest nocturnal avian predator in boreal and temperate areas of Eurasia. Eagle Owls are top predators that have been documented to prey on many medium-sized and even large avian and mammalian predators including, for example, red foxes *Vulpes vulpes*, pine martens *Martes martes*, Ospreys *Pandion haliaetus* and Goshawks *Accipiter gentilis* (Mikkola 1983, Korpimäki & Norrdahl 1989). Large owls and diurnal raptors have suffered from pollution and persecution throughout the world during the 20th century, making them endangered, and in some local cases, near to the point of extinction. In Finland, Eagle Owls suffered from high degrees of persecution due to a perceived threat to small game, however, subsequent studies into the owl's diet soon dismissed the scale of this perceived threat (Sulkava 1966, Mikkola 1970, Huhtala *et al*. 1976, Korpimäki *et al*. 1990). After WWII, Eagle Owl numbers declined throughout the entire European distribution range, which gradually led to the species becoming protected in the whole of Europe. In Finland, the Eagle Owl was partially protected in 1968, leading to full protection in 1983 (Valkama & Saurola 2005). Although this protected status has proved to be a major factor in the growth of its population since the 1970s (Valkama & Saurola 2005), the appearance of a new and abundant food niche may have also contributed to this growth as the owls soon learned to feed on the rapidly increasing brown rat *Rattus norvegicus* populations found in the dumps in southern and central Finland; the major distribution area of Eagle Owls in the country.

Brown rats belong to the typical food base of Eagle Owls in Finland and elsewhere (Sulkava 1966, Sulkava *et al.* 2008, Mikkola 1970, 1983, Huhtala *et al*. 1976, Korpimäki *et al*. 1990, review in Penteriani & Delgado 2019). In the breeding season, their proportion as prey items before the 1970s within the hinterlands was 5–10%, describing a "normal" background level of rats within a countryside landscape (Sulkava 1966, Sulkava *et al.* 2008, Korpimäki *et al*. 1990). The main prey items for the Eagle Owls are water vole *Arvicola terrestris* and *Microtus* voles (the field vole *M. agrestis* and the sibling vole *M. rossiaemeridionalis*), whereas hares (*Lepus* spp.) and forest grouse (Tetraonidae spp.) were the most utilized alternative prey for Eagle Owls breeding in the hinterlands far from villages and rubbish dumps (Sulkava 1966, Korpimäki *et al*. 1990). Whereas, in southwestern Europe, rabbits *Oryctolagus cuniculus* are the most important prey for Eagle Owls (Lourenço *et al*. 2015, Penteriani & Delgado 2019).

Since the 1960s the rise in the standard of living yielded more household waste and led to the establishment of municipal dumps, and more local garbage sites were started in larger villages. Since more edible wastes were carried to these garbage sites, rats learned to utilize these extra food sources, causing their noticeable increase (see Newsome *et al*. 2015). It is little wonder that nocturnal Eagle Owls near villages and towns quickly took advantage of the sudden abundance of these rats (see Marchesi *et al*. 2002), which are ideal-sized prey (mean body mass 400 g) as an alternative to their typical prey species, the water vole (mean body mass 170 g).

This paper studies the diet composition of Eagle Owls at varying distances from the dumps, focusing on the proportions of rat numbers. Data is also presented on the breeding success and breeding density of Eagle Owls in relation to their distance from the dumps, where it can be estimated whether breeding success improved


Fig. 1. Development of number of dump sites in Central Ostrobothnia western Finland from 1955 to 2020.

due to the extra availability of food (rats) and whether it had a role behind the recovery and remarkable growth of the Finnish Eagle Owl population since the beginning of the 1970s, but also in its gradual decline since the early 1990s, which coincided with the closing of the dumps and the inevitable decline in the availability of rats as an easy source of food for the Eagle Owls.

## 2. Materials and methods

### 2.1. Study area

The study was conducted in the border area of counties of Central and North Ostrobothnia totaling roughly 12000 km², in western Finland (63°54'N, 24°30'E) during 1966–2021. Mapping of Eagle Owl territories and nest searches were mainly conducted by Kauko Huhtala and his co-workers in the mid and late 1960s. The first nests were discovered by inquiries from locals who knew many traditional nesting sites (*e.g.* rocky areas), where Eagle Owls had traditionally nested earlier. Later, territories were also found by listening to the call of males in early spring (January to March) (*e.g.* Bergerhausen & Willems 1988, Olsson 1997). Searches of nests were initiated in early June each year in areas where hooting Eagle Owls were observed. Fresh droppings, feathers, downs and pellets below the roosting sites helped to locate the core of the territory, and careful searches of the nests were concentrated in these core areas. The Eagle Owl territories were mapped in the central study area, Sievi and its neighbouring municipalities in the late 1960s. Thus, the location of territories and nests were mostly known when the long-term study was initiated in 1970. All known territories and nest sites were inspected annually between 1970 and 2020, and new territories were actively searched. Generally, nests are in the river valleys near settlements and agricultural fields.

Food remains of the Eagle Owl were collected from nest cups and pellets found below roosting sites were used to study the diet composition. Collections were made one to several times for each nesting site. Bird ringers did the main part of the collection when ringing the owlets at the age of 3–4 weeks. Kauko Huhtala did a more detailed search of food remains.

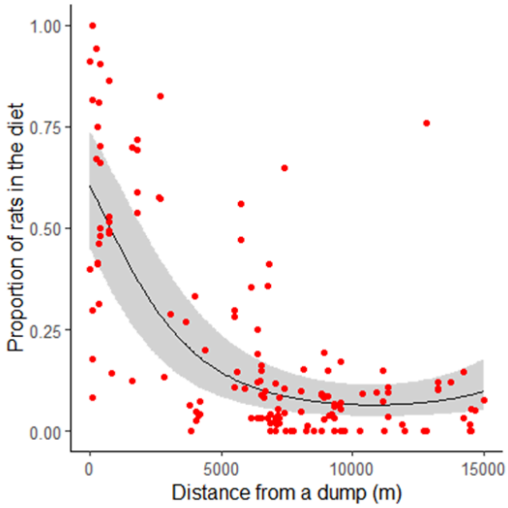


Fig. 2. Proportion of brown rats (*Rattus norvegicus*) in the diet of the Eagle Owl (*Bubo bubo*) as a function of distance to the nearest dump site. Black line represents the model predictions based on the final model (see text for details) with the grey areas representing the 95% confidence interval. Red dots are the data points. Pooled data from 1966-2015.

Identification of prey items was done by comparing bones, nails, hairs and feathers found with reference material of known species in the Zoological Museum, University of Oulu, Finland. Food material consisted of 10551 identified prey individuals collected from 167 nest sites. However, 14 nest sites were removed from the analyses due to the lack of geographic coordinates. One nest was left out as less than 10 identified prey individuals were found. The final data set consisted of 152 nesting sites and 9630 prey individuals from 1966–2015.

Brood size data consisted of 731 nestlings from 294 broods ringed at the age of 3–4 weeks during 1974–2021 as available from the Ringing Center of the Natural History Museum in Helsinki.

The location of all study area dumps, as well as the length of existence (when founded and when closed), were obtained from the Finnish Environment Institute. Distances from the Eagle Owl nests were measured from the nearest two or three dumps, while also considering the levels of activity of the site. Some minor errors may have occurred by the accuracy of nest coordinates since a part (42%) of them were announced by 1000 m accuracy while others by 100 m accuracy.

## 2.2. History of dumps

Sites for community waste were first necessary in the big municipalities. Later, they were found even in proximity of middle-sized and small villages. Their number started to increase from the beginning of the 1960s, culminating at the beginning of the 1990s and afterwards declined steeply (Fig. 1). Those remaining are not dumps anymore but recycling and packing stations for burning the waste that cannot be recycled. This has meant the depletion of available prey animals like rats, gulls and corvids for their predators. At large and poorly managed dumps, the rat densities can be very high: in one study conducted in southwestern Finland in 1994, the highest density was 950 individuals / hectare (Mikkonen *et al*. 2005).

## 2.3. Statistical analysis

We analyzed the proportion of rats in the Eagle Owl diet by fitting generalized linear mixed models (GLMM) with binomial error distribution and logit link function. The brood size was analyzed using generalized linear mixed models with Poisson error distribution and log link function. There were only 5 diet data sets and 14 brood size observations that were longer than 15 km distance from the closest dump. These observations were removed from the GLMMs because the regression lines would have been unreliable for these distances. As a result, we had 147 nests for diet analysis and 280 nests for brood size analysis. For both analyses, we fitted as explanatory variables the distance from the closest dump (standardized to facilitate numerical stability) both as a linear and a quadratic term. To account for potential annual and spatial variation we also included the year and the latitudinal coordinate as random intercept terms (assuming a normal distribution with zero mean and variance to be estimated). We did not include the longitudinal coordinate in the models, because the latitudinal and longitudinal

Table 1. Estimates for the parameters in the final models for the proportion of rats in the diet and brood size of the eagle owl. 95% CI refers to the 95% confidence interval of the estimate, sd is standard deviation, *β* denotes the estimation of regression for the curve

| Response variable | Parameter | Estimate | |
|---|---|---|---|
| Proportion of rats in the diet | ***Fixed terms*** | ***β*** | ***95% CI*** |
| | Intercept | -2.19 | -2.83, -1.56 |
| | Distance to a landfill site | -0.93 | -1.02, -0.85 |
| | Distance to a landfill site² | 0.46 | 0.38, 0.53 |
| | ***Random terms*** | ***sd*** | ***95% CI*** |
| | Year | 0.94 | 0.73, 1.24 |
| | Latitudinal group | 0.90 | 0.58, 1.48 |
| Brood size | ***Fixed terms*** | ***β*** | ***95% CI*** |
| | Intercept | 0.92 | 0.84, 0.99 |
| | Distance to a landfill site | -0.07 | -0.15, 0.003 |
| | ***Random terms*** | ***sd*** | ***95% CI*** |
| | Year | 0.00 | 0.00, 0.10 |
| | Latitudinal group | 0.00 | 0.00, 0.12 |

coordinates were strongly positively correlated for both data sets (diet data: Pearson $\rho = 0.67$; brood data: Pearson $\rho = 0.67$). To facilitate the analysis the latitudinal coordinate (metric coordinate) was transformed into 10 km groups that resulted in 13 latitudinal groups for the diet analysis (from one to 32 nests per group) and 19 latitudinal groups for the brood size analysis (from one to 40 broods per group). The diet analysis included 41 years (from one to 15 nests per year) and the brood size analysis 38 years (from one to 26 broods per year).

We also fitted for both analyses, a model excluding the quadratic term for the distance to the closest dump and chose the model with a lower Akaike information criterion (AIC) value as the final model. All models were fitted using program R 4.4.1. (R Core Team 2024) and R package lme4 (Bates *et al*. 2015). Model validation for the final models was done using the package DHARMa (Hartig *et al*. 2024). Model validation results were acceptable, although for both analyses the data was somewhat under-dispersed compared to the assumed binomial and Poisson distributions. This was probably due to most observations being relatively close to the zero boundary where there is less room for variation compared to higher values.

In addition, based on the above GLMM analysis for the proportion of rats in the Eagle Owl diet, we defined a threshold of distance to the closest dump for nests located within the influence of a dump versus the Eagle Owl nests outside of it. This distance threshold was set at 6 km (see Results). We then divided the nests according to this 6 km threshold and described the diet of the Eagle Owl inside *versus* outside the 6 km distance from a dump. Finally, we defined three distance groups (0–6 km, 6–12 km and 12–18 km from a dump) and calculated mean Eagle Owl nest and brood densities for each distance group over the whole study period.

# 3. Results

## 3.1. Eagle Owl's diet related to the distance to dump

For the proportion of rats in the Eagle Owl diet, both the linear and quadratic terms for the distance to the closest dump were statistically significant (Table 1). The model predicted a steep decline in the proportion of rats in the diet from close to a dump (model prediction at 100 m from a dump site, mean [95% confidence interval (CI)]: 0.59 [0.44, 0.73] to about 6000 m (0.11 [0.06, 0.19]) where after the proportion of rats remained relatively stable (prediction at 12 000 m: 0.07 [0.04, 0.12]) (Fig. 2).

Rats were the most abundant prey in the nests closer than 6 km from the dump while water vole took the first position in nests further than 6 km away (Table 2). Yet, water voles were important prey also near the dumps. Large prey like hares (*Lepus timidus*, *L. europaeus*) and muskrats (*Ondatra zibethicus*) also compensated for rats in nests farther than 6 km from the dumps. 80 per cent of hares were juveniles. The percentage of field voles was relatively high, 10–20% of prey items being, by far higher, more than 6 km from the dumps. No differences were found among other prey groups between these distances. Data on home range and territory sizes of the Finnish Eagle Owls is scarce, but satellite-tracking of breeding males has revealed that during the breeding season they mainly hunt within 5–6 km from their nest (J. Valkama, unpubl. data).

## 3.2. Nest density and breeding success related to the distance to dumps

In total, 178 Eagle Owl nests were within 6 km of a dump, 131 nests within 6–12 km and 40 nests within 12–18 km. This resulted in the total nest number/km² for the whole study period of 1.04 (0–6 km), 0.39 (6–12 km) and 0.07 (12–18 km) nests per km². For the number of chicks produced within these distance groups, the corresponding figures were 2.81, 0.93 and 0.16 chicks per square km. Adjusting these figures annually to 100 km² gives mean densities outside the effect of dumps from 0.2–0.8 nests per 100 km², which is close to that found in earlier studies for South Finland (Table 3, References). The closest group had 2.7 times more nests and 3.0 times more chicks/km² than the next one, while the furthest group had only 6–7% of those of the closest group (Fig. 3).

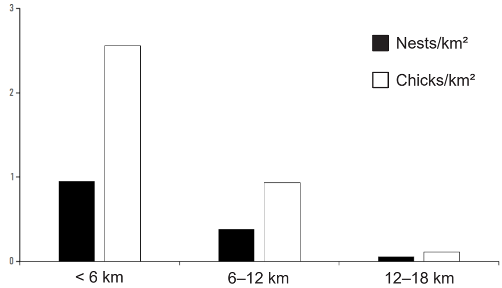


Fig. 3. The total density of discovered eagle owl's nests (nests/km²) and owlets (chicks/km²) within three distance groups from dumps during the years 1974-2014.

For the brood size (*i.e.* number of 3–4-week-old offspring), GLMMs the quadratic term for the distance from the closest dump, was not supported, therefore the final model included only the linear distance term. The final model predicted a slight linear decrease in the brood size from 2.79 [2.44, 3.20] owlets at 100 m from a dump to 2.52 [2.33, 2.71] owlets at 6000 m and 2.26 [1.98, 2.59] owlets at 12 000 m (Fig. 4). However, the linear term for the distance to the closest dump was not quite statistically significant (Table 1). The standard deviations for the random terms were both estimated at zero (Table 1). This again suggests that variation in the brood data is relatively low (*cf.* the model validation results). The zero boundary fits for the random intercept terms essentially means that the model reduces to the regular generalized linear model excluding the random terms. For this type of model that only includes the linear distance term the parameter estimates for the distance term were identical to the final model.

# 4. Discussion

We found that the proportion of rats in the diet of Eagle Owls during the breeding season declined as the distance from the dump increased: the

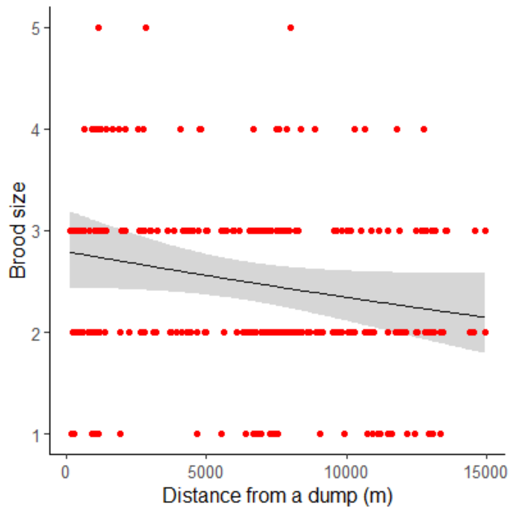


Fig. 4. The brood size of the eagle owl in relation to the distance from the closest dump site. Black line represents the model predictions based on the final model (see text for details) with the grey areas representing the 95% confidence interval. Red dots are the data points. Pooled data from 1974-2001.

proportion of rats in the diet near the dump was close to 70% of all prey items but <10% of prey items >6 km from the dump. At the distance of >6 km from the dump, water voles were the main prey, field voles being the second and rats the third most important by number. The Eagle Owls raised large broods near the dumps, with their breeding success being 2.7 times and breeding density 2.5 times higher near (<6 km) the dumps than further away from them. These results showed that large-scale "supplementary feeding" (rich rat food resources produced by dumps during the 1960s to early 1990s) notably increased the offspring production and breeding density of the Eagle Owl population. There is also historical evidence how the arrival of a dump (*i.e.* the initiation of "supplementary feeding") changed the diet in one Eagle Owl territory in Kuopio, eastern Finland: in 1890 the Eagle Owl diet contained 50% of water vole and only 15% of rats, while in the 1970s, when the active Kuopio city dump was less than 3 km from that territory, the proportion of rats in the diet was as high as 73% but that of water vole only 12% (Mikkola 1974).

There was a clear difference in the proportion of brown rats and water vole between dump nests (<6 km) and those pairs that nested in the next zone (>6–12 km from the dump site). Rat numbers dominate in the nests close to dumps while water voles dominate in hinterland nests. Rats formed almost the whole diet of Eagle Owls during the nesting period, while they usually

Table 2. Diet of the eagle owl in relation to distance to the dump site in Central Ostrobothnia western Finland in 1971-2016. The percentages refer to the proportions of the specified taxa out of the total number of identified prey specimens (N) within each distance group.

| Distance from the rubbish landfill site | | < 6 km | > 6 km |
|---|---|---|---|
| | | % | % |
| Hares | *Lepus timidus, L. europaeus* | 5.5 | 6.0 |
| Muskrat | *Ondatra zibethica* | 0.6 | 2.2 |
| Water vole | *Arvicola terrestris* | 30.9 | 46.6 |
| Field vole | *Microtus agrestis* | 15.4 | 19.1 |
| Birds | *Birds total* | 5.0 | 6.2 |
| Brown rat | *Rattus norvegicus* | 40.7 | 8.3 |
| Frogs | *Rana sp., Bufo bufo* | 1.9 | 3.5 |
| Other prey | *Mammalia, Reptilia, Pisces* | 7.9 | 5.8 |
| Number of prey items | | 2855 | 7696 |

Table 3. Numbers and mean annual densities of nests and chicks within spherical discs (annuluses) around the dumpsites in 1974-2021.

| Distance classes (km) | 0–3 | 6–12 | 12–18 |
|---|---|---|---|
| Spherical areas (km²) | 113 | 452 | 1017 |
| Partial areas (annuluses) | 113 | 339 | 678 |
| Number of nests | 118 | 131 | 40 |
| Number of chicks | 318 | 314 | 88 |
| Number of nests/km² | 1.0 | 0.4 | 0.1 |
| Number of chicks/km² | 2.8 | 0.9 | 0.2 |
| Mean annual number of nests/100 km² | 2.2 | 0.8 | 0.2 |
| Mean annual number of chicks/100 km² | 6.0 | 2.0 | 0.3 |

account for less than 70%, on average. Generally, rats are the second most common prey after water vole, but due to their larger size, rats are equally as important in terms of biomass. Based on stomach analyses, male Eagle Owls consumed twice as many rats as females (Mikkola & Tornberg 2014), which may suggest that males have hunted more frequently at dumps than females. In addition, male Eagle Owls are mainly responsible for hunting and on prey deliveries to the nest in the breeding season, and thus more used to take benefit from rat-rich waste dumps than females that stay in the vicinity of the nest during courtship feeding, egg-laying, incubation and brooding periods. Compared to other regions, rats are valuable prey close to human settlements and less so in other geographical areas (Marchesi *et al*. 2002, Penteriani & Delgado 2019).

During winter, rats are much more available than water vole, which occupy below-ground nests protected by deep snow layers. The much smaller field voles have a high share in the diet by number, likely due to their abundance, especially in peak years of the 3–4-year population cycle of field voles. In South Ostrobothnia (approx. 150 km south of our study area), Korpimäki *et al*. (1990) showed that the proportion of two *Microtus* voles (the field vole and the sibling vole) in the diet of breeding Eagle Owls was, by prey numbers, positively correlated with the abundance indices of these voles in the field, although their average proportion by number was 25% and by weight only 4%, while those of brown rats 30% and 44%, respectively. This data indicates that even in peak years of voles when their densities can rise to 100–200 individuals per ha in grassy habitats (Korpimäki *et al*. 2005), rats were more profitable prey for Eagle Owls than small voles (mean body mass 25 g).

We found that breeding success of Eagle Owls was 2.7 times higher in the vicinity (<6 km) of the dumps than further away from them. This was because, in dumps, the rats formed an extremely dense and easily available food niche. Thus, the parent owls within “dump territories” were apparently in better physical condition, thereby being able to produce more eggs. In contrast, Eagle Owl pairs breeding farther away from dumps probably suffered more frequently from food shortage, resulting in smaller clutch sizes. Corresponding effects have been found among mammalian predators utilizing waste food provided by dumps (Newsome *et al*. 2015). Similarly, starvation amongst the brood was more likely in more distant territories than those next to dumps. Some Eagle Owl parents probably returned hunting even farther than 6 km to these dense rat patches, as can be deduced from our analysis (Fig. 2), because the energy consumption of searching for rat prey occupying dumps is relatively low. Rats, as prey items, are also twice as large as water voles and 16 times larger than *Microtus* voles. Therefore, they probably are far more profitable prey for Eagle Owls than water vole and small voles close to the nests, although transportation costs up to 6 km from the nests can be relatively high. The difference in the brood size between close *vs*. distant sites was, however, not that significant, while the chick production was higher due to more nests in the vicinity of dumps *vs*. hinterlands. There were also broods with only 1–2 chicks in the vicinity of dumps, remarkably lowering the mean. Disturbances in the dumps and close by may have caused breeding failures. So, some females could have made new nesting attempts explaining the below average number of chicks or that some young ones have already left the nest before ringing. It is a well-known fact that high-level nutrition advances laying date at least in other birds of prey (*e.g*. Korpimäki & Hakkarainen 1991, Aparicio 1994, Korpimäki & Wiehn 1998).

In addition, that owl pairs living near dumps had larger broods, their nestling survival was also better than in pairs living on a typical food base. Broods raised near the dumps and tracked after leaving the nest until independence did not lose owlets, while Eagle Owl broods found within forested hinterland areas tended to lose, on average, one offspring up to the post-fledging period (Kauko Huhtala, unpubl. data).

The number of nests found during the study years was 2.5 times larger in the surroundings of dumps than further away from them (>6 km). This is the first time "experimental food supplementation" is increasing the country-wide breeding density of a top predator. In our study area, approx. 40% of the Eagle Owl nests were within the 6 km range *i.e.* under the influence of the dumps. Valkama & Saurola (2005) estimated that at least 1000 Eagle owl pairs (approximately one-third) were nesting under the influence of the dumps and their high population of rats during the 1980s–1990s. The shift of the Eagle Owl population from the hinterland to the proximity of dumps and villages occurred from the 1960s to the 1980s (Helppi & Kalinainen 1984).

We suggest that the rise of the Eagle Owl population has been mainly due to an expanded dump network throughout the country. New dumps were often established several times in a municipality after the old one was filled up or there was no space to enlarge it due to, for example, the spreading of the settlement areas close to them. This was typical in large cities that attracted people from the countryside. As more attention started to be paid to the environment, the sprawling of the dumps was seen as detrimental. Besides, dumping of the possible raw materials was not considered wise any longer and more attention was paid to recycling. Therefore, the number of dumps started to decline in the 1990s, which induced a decline in rat populations within the dumps. This led to a notable decline in breeding success and breeding density of the Eagle Owl population in Finland from the 1990s to 2000s (Valkama & Saurola 2005). From the 2010s onwards, wastes have been treated in large provincial waste stations, recycled and/or burnt. This remarkably reduced the living space of rats, their food and thus reproduction possibilities. Therefore, rat-rich patches for hunting Eagle Owls have drastically declined. In addition, in the 2000s peak densities of vole cycles have also diminished (Korpela *et al*. 2013) and populations of hares and forest grouse have substantially declined, too (Tornberg 2021). These declines of important prey species and groups have induced a severe decline in the Eagle Owl population. According to the monitoring, and earlier more or less accurate estimates of the Eagle Owl population in Finland likely reached its peak density, over 3000 pairs in the early 1990s (Valkama *et al*. 2014), whereas it has steadily declined by a 3% annual rate (Honkala *et al*. 2023). In 2019–2024 the population estimate for Eagle Owls in Finland was 830 pairs (Lehikoinen *et al*. 2025). The Eagle Owl was red listed as a highly endangered species in Finland in the late 2010s (Hyvärinen *et al*. 2019).

It is concluded that the rise and fall of dumps formed an important countrywide "food-supplementation experiment" because, near the dumps, Eagle Owls subsisted almost exclusively on brown rats. This rat-food addition notably increased the offspring production of Eagle Owls, and induced clustering of Eagle Owls close to the dumps and increasing breeding density. Similar effects have been found in many other birds having access to anthropogenic food subsidies (Oro *et al*. 2013). In this sense, our results are consistent with the similar results obtained for Eagle Owls using rabbits in southwestern Spain. When young rabbits were available in the home range, egg-laying started earlier, and offspring production improved. When rabbits were less available, Eagle Owls increased their home range size to obtain alternative prey, adding their dietary diversity, which may also require higher movement speed (Lourenço *et al*. 2015). Compared to unfed control pairs fed pairs usually advanced their initiation of egg-laying, clutch size and breeding success in the earlier food supplementation experiments (Boutin 1990, Ruffino *et al*. 2014). However, notable effects on breeding density remained unknown.

This “food-addition experiment” with Eagle Owls was unique in at least two ways. First, the semi-natural experiment was performed on a large spatial and temporal scale covering thousands of square km and including at least two decades, while in other experiments food was supplemented for some, usually 10 to 20 randomly selected nests during less than five breeding seasons. Second, Eagle Owls still needed to hunt and kill free-running rats which had anti-predatory behaviours and deliver rats to their nests. In other food-supplementation experiments with avian predators, extra food (dead specimens like laboratory mice, chickens, quail or pigeons) was usually provided by experimenters directly to the nest (*e.g.* Korpimäki 1989, Aparicio 1994, Korpimäki & Wiehn 1998, Hörnfeldt *et al*. 2000, Ward & Kennedy 1996, Kennedy & Ward 2003, McKinnon *et al*. 2024). Therefore, Eagle Owls still carried the searching, killing and transportation costs of food items from dump to their nests at a distance. Compared to other studies concerning the anthropogenic food subsidies where mainly immobile (dead) food was provided in dumps (*e.g*. Oro *et al.* 2013, Newsome *et al.* 2015, Oppel *et al.* 2025), effects on the target populations were, however, fairly like we found, namely increased productivity and thereby population growth. Oro *et al.* (2013) stressed accordingly that wide, long-lasting “food-supplementation experiments” with a sudden cessation offer much more reliable results than sporadic, local planned experiments can do.

The Eagle Owl population has undoubtedly collapsed in Finland, but we do not know yet whether it is purely due to declined productivity by vanishing high productive breeding areas such as dumps. Therefore, we need more data on the over-winter survival of Eagle Owls hatched near dumps and forested hinterlands.

## Huuhkajakannan nousu lisääntyneiden rottakantoja ylläpitävien kaatopaikkojen vuoksi ja hupeneminen niiden sulkemisen myötä. Laaja-alainen, pitkäkestoinen "ruokintakoe"

Ravinnon on osoitettu tavallisesti olevan tärkeä parantuneen lisääntymismenestyksen tekijä selkärankaisilla eläinlajeilla tehdyissä lisäruokintakokeissa. Huippupedoilla tehdyt laaja-alaiset lisäruokintakokeet ovat olleet kuitenkin harvinaisia. Huuhkaja (*Bubo bubo*) on Euraasian lauhkean vyöhykkeen suurin yöaktiivinen lintupeto. Tutkimme tämän huippupedon ravintovalikoimaa ja lisääntymismenestystä suhteessa etäisyyteen kaatopaikoista, jotka ylläpitävät suuria rottamääriä (*Rattus norvegicus*), erästä huuhkajan merkittävimmistä saalislajeista. Kaatopaikat lisääntyivät Suomessa 1960-luvulta 1990-luvulle, jonka jälkeen niiden määrä jyrkästi väheni johtaen samalla rottapopulaatioiden vähenemiseen. Samanlainen huuhkajamäärien kehitys seurasi tätä ilmiötä. Rottien osuus huuhkajan ravinnossa oli kaatopaikkojen lähellä korkea, keskimäärin 70 % väheten 10-15 % 6-7 km päässä kaatopaikoista. Vastaavasti 3-4-viikkoisten huuhkajan poikasten lukumäärä väheni suhteessa etäisyyteen kaatopaikasta siten, että niitä oli 0,5 poikasta vähemmän 10 km päässä kaatopaikasta. Tutkimuksen aikana kaikkien löydettyjen pesien lukumäärä oli kaatopaikkojen lähellä 2,7 kertaa suurempi kuin kauempana. Ylimääräisen ravinnon saatavuus kaatopaikkojen lähellä (siellä elävät rotat) aikaansaivat luultavasti huuhkajapopulaation kasvun ja kaatopaikkojen sulkemisten jälkeisen vähenemisen.

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