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Thirty-eight years after: changes in the diet of the long-eared owl *Asio otus* in a protected area of NW Italy

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Abstract - The diet of long-eared owls was studied by analyzing pellets collected in the winters of 1985 and 2021 in a protected areas of NW Italy. In 1985, the owl diet was dominated by the wood mouse *Apodemus sylvaticus*, birds (*Ploceidae* sp.), and the Savi's vole *Microtus savii*; in 2021, the diet is dominated by the harvest mouse *Micromys minutus*, the wood mouse, and the bank vole *Myodes glareolus*. The shift in diet only partially reflects changes over time in the arable land surrounding the nature reserve. While the increase in the number of bank voles over 38 years can be explained by the increase in forest cover, the increase in the number of rice field mice contrasts with the reduction in their preferred habitats; the marshes have disappeared, the ditches have been reduced, and riparian vegetation has largely been removed. In addition, the most stable agroecosystems, such as poplar groves and meadows, have been largely replaced by intensive cereal and soybean crops. It is likely that improved harvesting and the expansion of intensive cultivation may partly explain some dietary shifts, such as the decline in birds, while the increase in harvest mice may be the effect of increased opportunistic predation on small populations surviving in suitable but fragmented habitats. As the harvest mouse is in decline throughout its range, natural and anthropogenic habitat changes may indirectly lead to increased predation on a threatened species and undermine its conservation.

Key words: long-eared owl, *Asio otus*, prey, pellets, rodents, agricultural intensification.

Riassunto - Trentotto anni dopo: cambiamenti nella dieta del gufo comune *Asio otus* in una riserva naturale dell'Italia nord-occidentale.

La dieta del gufo comune Asio otus è stata studiata analizzando le borre raccolte negli inverni del 1985 e del 2021 in una riserva naturale dell'Italia nord-occidentale. Nel 1985, la dieta dei gufi era dominata dal topo selvatico *Apodemus sylvaticus*, dagli uccelli (*Ploceidae* sp) e dall'arvicola di Savi *Microtus savii*; nel 2021, la dieta è dominata dal topolino delle risaie *Micromys minutus*, dal topo selvatico e dall'arvicola rossastra *Myodes glareolus*. Le modificazioni nella dieta riflettono solo in parte i cambiamenti avvenuti nel tempo nei terreni coltivabili che circondano la riserva. Mentre l'aumento dell'abbondanza dell'arvicola rossastra nel corso di 38 anni puт essere spiegato con l'aumento della copertura forestale, l'incremento del topolino delle risaie è in contrasto con la riduzione degli habitat elettivi: le zone umide sono scomparse, fossi e corsi d'acqua sono diminuiti e la vegetazione ripariale è stata in gran parte eliminata. Inoltre, gli agroecosistemi più stabili, come i pioppeti e i prati, sono stati in gran parte sostituiti da colture intensive di cereali e soia. È probabile che il miglioramento delle tecniche di raccolta e l'espansione delle colture intensive possano spiegare in parte alcuni cambiamenti alimentari, come il declino degli uccelli, mentre l'aumento del topolino delle risaie potrebbe essere l'effetto di una maggiore predazione opportunistica sulle piccole popolazioni che sopravvivono in habitat adatti ma frammentati. Poichй il topolino delle risaie è in declino in tutto il suo areale, i cambiamenti dell'habitat, sia naturali che di origine antropica, possono portare indirettamente ad impatti aggiuntivi che ne compromettono ulteriormente la conservazione; fra questi l'aumento opportunistico della predazione su una specie a distribuzione locale fortemente frammentata.

Parole chiave: gufo comune, *Asio otus*, predazione, borre, roditori, intensificazione agricola.

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INTRODUCTION

The long-eared owl *Asio otus* (L., 1758) is a nocturnal predator that prefers to hunt on open fields, usually avoiding forests and dense woodlands (Wijnandts 1984; Hagemeijer & Blair 1997; Zmihorski *et al*., 2012). In southern Europe, long-eared owls overwinter in communal roosts that can be formed by tens of birds; this makes it easy and profitable to collect pellets and obtain data about the diet (Mikkola, 1983). Long eared owl diet has been extensively studied all over its distributional range and a huge amount of information on winter diet is available (Birrer, 2009); most of the studies were conducted over relatively short periods (Zimmerman, 1963; Korpimäki, 1992), but long-time studies on response of long eared owl have shown a functional response to changing abundance of its preys (Tome, 2003; Sharikov *et al*., 2014; Tulis *et al*., 2015).

Diachronic studies on diet changes allow the analysis of climatic and environmental variation and its effect on feeding ecology (Milligan *et al*., 2009). Time can affect habitat characteristics, seasonality, prey availability and behavior (Tablado *et al*., 2014, Milana *et al*., 2018); ecological and behavioral traits can be affected by variation in temperature, rainfall and snowfall, trend of chemical use in agriculture, reduction of microhabitat, decrease of stable agro-ecosystems as meadows, increase of afforested patches (Green *et al*., 2001).

The general outcome of several hundreds of papers published on winter diet of long-eared owls can be summarized as follows: i) it can behave as an opportunistic predator (Tome, 1991; Shao & Liu, 2006; Bertolino *et al*., 2011); ii) its preferred preys are mainly voles (Microtinae) and particularly the common vole *Microtus arvalis* in central and northern Europe (Birrer, 2009); iii) meteorological conditions can affect the diet and hunting success (Canova, 1989; White, 2008; Sharikov & Makarova 2014), and iv) brood sizes and fledging rates depend on food availability (Lehikoinen *et al*., 2011, Jackson & Cresswell, 2017).

The prevalence of *Microtinae* in diet has been considered sometimes as a feeding specialization (Cecere & Vicini, 2000); however, the long-eared owl may behave as a plastic predator, quickly and opportunistically switching from the most abundant local prey to other (Nilsson, 1981; Canova, 1989; Rubolini *et al*., 2003). The preference for voles is probably due to the prevalence of these rodents in open farmland of central and northern Europe; where Microtinae are nearly absent, as in the Italian northern plain, mice (Muridae) usually predominate in the diet (Schmidt, 1973; Galeotti & Canova, 1994; Garcia Gonzales & Cervera Orti, 2001; Bertolino *et al*., 2011).

Environmental or human-induced factors as land-use changes, climate change, forest and agro ecosystems management, and rodenticide use, can affect owls (Mikkola, 1983; Haug & Oliphant, 1990; Birrer, 2009; Spadetto *et al*., 2024). Aschwanden *et al*. (2005) reported that the long-eared owl is declining in several areas of Europe as a consequence of the intensification of agricultural practices and the related decline of small mammals. Balestrieri *et al.* (2019) have recently demonstrated that the diet of an owl guild in a protected area in northwest Italy changed from 1995 to 2015 and that some agricultural practices are the most probable cause. As the Long-eared owl can show a functional response to prey abundance variation (Korpimäki, 1992; Tome, 2003), the diachronic study of diet variation can provide useful information about prey ecology and their response to habitat change over time. The aim of this paper is then to analyze changes that occurred in the diet of a local wintering population, as assessed by the analysis of pellets collected in 1985 and 2021.

MATERIALS AND METHODS

Study area

The study area coincided with the Site of Community Interest "Monticchie" (SCI IT 209000; 450836 N, 093854 E). The site covers ca. 250 ha on the left bank of the river Po, of which 24.5 ha are plain hygrophilous forest and 225.5 ha agricultural land. Residual forested areas consist of alluvial woods with alder *Alnus glutinosa*, white willow *Salix alba,* common ash *Fraxinus excelsior,* and deciduous riparian woods with oak *Quercus robur* and elms *Ulmus* spp. The buffer agricultural area is composed of nearly 70% maize, 15% meadows, 10% hedgerows and woodlot, and 5% ditches and channels. Weather stations of Codogno (LO), Piacenza (PC), and Sarmato (PC) provided archive data on yearly mean rainfall (mm), air humidity (%), and average temperatures (°C) (ARPA Emilia Romagna, ARPA Lombardia).

Pellet analysis and small mammal sampling

A total of 120 pellets were collected in January 2021 at a communal winter roost of 7-11 birds and compared with a sample of 120 pellets collected before the huge snowfall of December 1984-January 1985 (data already published in Canova 1989; Tab. 1). Pellets were dry opened by hand and forceps; each pellet was treated as a single sample.

Preys were identified as the minimal number of individ-

Tab. 1 – Comparison between diet composition of the Long-eared owl in 1985 and 2021. Statistical significance in relative frequency (i.e., number of individuals of each species/total number of individuals × 100) is tested by χ^2 and Holm-Bonferroni Sequential Procedure. / Confronto tra la composizione della dieta del gufo comune nel 1985 e nel 2021. Il test χ^2 e la Holm-Bonferroni Sequential Procedure sono stati adottati per il confronto statistico delle frequenze relative nei due periodi (numero di individui di ciascuna specie/numero totale di individui × 100).

	1985				2021				χ^2	p
	n	%	b	%	n	%	b	%		
Arthropoda	0	0	0	-	2	1.0	4	0.1	2.0	ns
Aves (Ploceidae)	26	14.5	390	12.8	3	1.5	45	1.7	16.7	*
Crocidura suaveolens	4	2.2	26	0.8	3	1.5	18	0.7	0.14	ns
Myodes glareolus	7	3.9	126	4.1	32	16.2	576	21.5	16.1	*
Microtus savii	20	11.2	280	9.2	16	8.1	224	8.4	0.44	ns
Apodemus sylvaticus	114	63.7	2166	71.0	43	21.7	817	30.5	32.1	*
Micromys minutus	8	4.5	64	2.1	90	45.5	720	26.9	68.6	*
Rattus norvegicus	0	-	0	-	4	2.0	200	7.5	4.0	ns
Muridae	0	-	0	-	3	1.5	45	1.7	3.0	ns
Microtidae	0	-		-	2	1.0	30	1.1	2.0	ns
Total preys	179		3050		198		2679			
Pellets		120				120				
Pellet size		36.9×17.3				51.9×17.4				
Preys/pellet	1.49±0.78		25.4		1.65±0.80		22.3			

ns, not significat; n, frequency; b, weight; *significant difference.

uals, which we were able to identify according to the same anatomical parts of bones observed under a binocular microscope and then compared with identification keys (Chaline, 1974) and our own archive collection. Estimates of prey biomasses were derived from specimens collected in the study area or literature for Brown Rat *Rattus norvegicus* (Di Palma & Massa 1981), lesser white-toothed shrew *Crocidura leucodon*, bank vole *Myodes glareolus*, wood mouse *Apodemus sylvaticus* (Canova *et al.*, 1999); an average weight of 15 g was assigned to birds, *Muridae* and *Microtidae* undetermined.

Small mammal abundance was estimated by trapping sessions carried out in 1984 and 1986, 1994 and 2003 (Canova, 1992; Gaudenzi, 1995, Filippini 2004). Originally, trapping sessions were carried out in six habitats in the study area (marshes, woodland, hedgerows, crops and meadows, ditches, and poplar groves). In the '80s, small mammals were trapped by 64 snap traps, singly arranged in an 80×80 nr grid at 10-m intervals. Grids were located in woodlands, marshes, poplar groves, and meadows, while 30-trap transects of snap traps were arranged along hedgerows and drainage ditches. All traps were checked daily, and trapped individuals were removed and bait replenished. Each trapping session lasted 72 hours. In 1994 and 2003, small mammals were trapped by 100 live Sherman traps singly arranged in a 10×10 grid at 12-m intervals in woodlands, poplar groves, and meadows (the marshes have meanwhile disappeared). A 30-live trap transect was arranged along hedgerows and drainage ditches. Each trapping session lasted 72 hours; each individual was individually marked by fur clipping, sexed, weighed, and released in the wild. To facilitate comparison between periods, quantitative data were normalized by applying a synthetic index of abundance on trapping data: n = (number of individuals of each species/number of trap night*trap number) *100. More details can be found in Canova (1989).

Statistical analyses

Data were expressed as percent frequency of occurrence [F = (number of individuals of each species/total number of pellets) × 100] and percent relative frequency of occurrence [RF = (number of individuals of each species/total number of individuals) × 100]. Raw frequency data were compared between periods by chi-square test, adopting a Holm-Bonferroni sequential procedure for multiple hypothesis tests; the procedure reduces the possibility of getting a statistically type I error when performing multiple tests (Holm, 1979). Standard non-parametric statistics were adopted to test for differences between indices.

RESULTS AND DISCUSSION

A total of 120 pellets were collected and analyzed in 1985 and 2021, and a total of 377 prey species were identified (179 in 1985 and 198 in 2021). In 1985, the wood mouse *Apodemus sylvaticus* was the most important prey (RF=63.7%); birds (*Ploceidae* RF=14.5%) and Savi's vole *Microtus savii* (RF=11.2%) were other relevant prey (Tab. 1). In 2021 long eared owls fed mostly on harvest mice *Micromys minutus* (RF=45.5%); the wood mouse (RF=21.7%) and the bank vole *Myodes glareolus* (RF=16.2%) were two other important preys, while Savi's voles were preyed on less frequently (RF=8.2%) than in the previous period (Tab. 1). The importance of other prey categories was negligible and did not significantly differ between the two periods. The mean number of preyed individuals per pellet varied from 1.49 in 1985 to 1.65 in the last period ($U=41.6$, $p<0.05$), while the average weight decreased from 25.4 g to 22.3 g ($U=38.3$, $p<0.05$). Diet diversity slightly increased from 1985 ($D=0.55$) to 2021 ($D=0.71$), and the size of pellets increased from 36.9 cm in 1985 to 51.9 cm in 2021 (Fig. 1).

The main differences between the diets of 1985 and 2021 concern the relative importance of birds, which declined considerably in 2021, and the harvest mouse, which increased sharply. In 1985, birds were mainly Ploceidae *Passer* sp., and their strong reduction in 2021 is consistent with the decrease of both sparrow species (*Passer montanus* and *Passer domesticus italiae*) in several areas of their distribution range (Brichetti *et al.*, 2007; Murgui & Macias, 2010; Birdlife International, 2021; Mohring *et al.*, 2021). The house sparrow population declined over the last decades in several parts of Europe; Brichetti *et al.* (2007) estimated

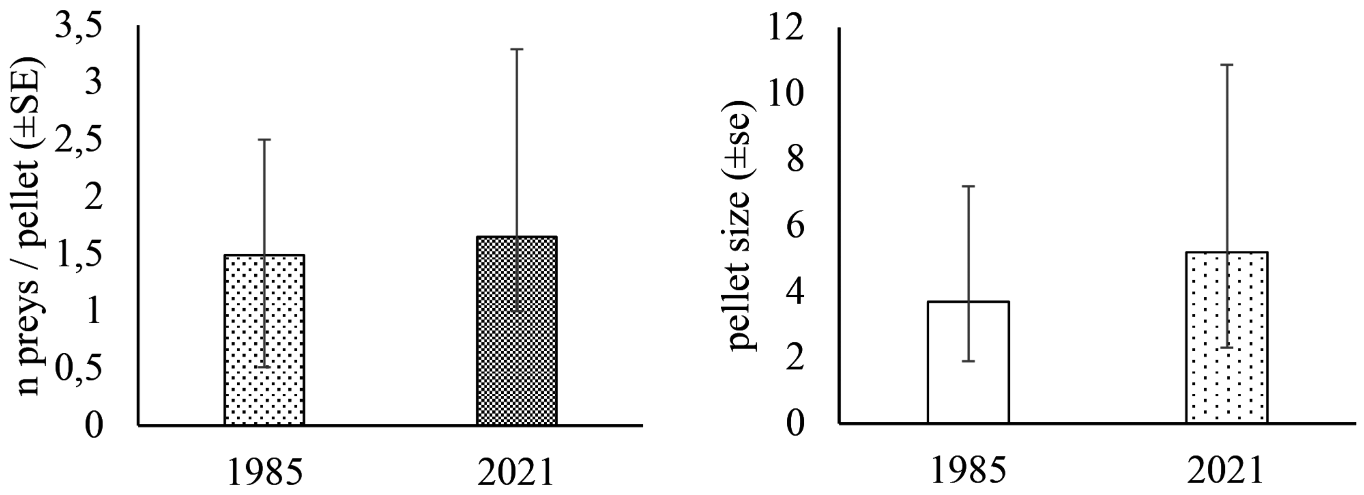

Fig. 1 – Variation of frequency of prey per pellet and pellet size during the study period. / Variazione della frequenza di prede per borra e delle dimensioni delle borre durante il periodo di studio.

a reduction of nearly 50% of the breeding population within 10 years. The reasons for this decline have been identified in winter food and nesting site shortage in the urban environment (Hole *et al*., 2002; Wotton *et al*., 2002; Mason, 2006) and the reduction of seed availability due to an increased efficiency of harvesting in rural habitats (Robinson *et al*., 2005; Brichetti *et al*., 2007). Harvesting loss depends on many factors; during harvesting, grain loss can be due to the setup of the threshing system of the machine, to the rotor and sieve (Riethmuller, 2021). The total grain loss can be up to 3% of the total harvest and reach a value of 100 kg/ha, which is an important food resource for many granivorous bird species during food shortage periods. Winter requires particular attention since seed-eaters are more affected by agricultural intensification than other farmland birds (PanEuropean Common Bird Monitoring Scheme, 2021; Neyens *et al*., 2023); in northern Italy, this is commonly associated with low food availability during winter due to autumn-sown cereal crops.

Data on harvest losses in the past are not available, and it is difficult to separate harvest improvement from productivity; however, CREA (2016) suggested the improvement of harvest in the field as a guideline of productivity in agriculture and Cannata (2014) show a reduction from about 4% to 3% of harvest loss from 2011 to 2022. It is then probable that the decline of the house sparrow in the agricultural landscape of the northern Italian plain can be partly explained by the reduction of trophic resources in the open field following late summer-autumn harvest. On the other hand, the role played by the reduction of residual seeds after harvesting in the decline of other granivorous species has been discussed by Coates *et al*. (2017) for the ring-necked pheasant *Phasianus colchicus,* Stanton *et al*. (2018), and Rigal *et al*. (2023) for several farmland species.

The increase of the harvest mouse in the diet of 2021 is perhaps the most interesting of the observed changes, both because of the role played by this prey in the increase in the prey/pellet ratio and the decrease in the mean biomass per pellet, and because its increase does not meet the reduction of its elective habitats occurred between 1985 and 2021. In 1985, the rice field mouse was indeed a common species in ditches and marshes (Canova, 1992), two habitats that have disappeared or been greatly reduced and altered over the years (Tab. 2). The species was locally abundant in the study area and declined from late ‘80s, becoming very scarce; nest winter of harvest mouse in vegetation along ditches decreased from 7.2 nest*km^{-1} in 1985 to 0 in 1991 (Canova *unpubl*.) and it is currently very scarce along the riparian vegetation of ditches (Tab. 3).

Harvest mouse is a declining species all over its distribution range (de la Peña 2003; Harris, 2008; Darinot, 2016); warmer seasons, reduction of wetland and water shortage in natural habitats are considered limiting factors for the species, moreover threatened by waterside cutting vegetation, an agricultural activity strongly increased also in our study area (Darinot, 2016; Vecsernyés, 2020). Despite the reduction of its abundance (Perrow & Jowitt 1995), an increase in owl prey has been observed by Love *et al*. (2001).

Tab. 2 – Habitat changes (%) in the foraging area surrounding roosts in 1985 and 2021. It was considered as a circle of a 1000 m ray centered on the roost, corresponding to about 320 hectares. / Variazione percentuale della superficie di habitat nell’area di foraggiamento circostante i posatoi nel 1985 e nel 2021. È stata considerata una circonferenza di 1000 m di raggio centrata sul posatoio, corrispondente a circa 320 ettari.

	1985	2021	Δ1985-2021 (ha)
Marshes (%)	7.7	0	- 24.6
Woodland (%)	14.1	19.1	+16.0
Poplar grove (%)	22.3	2.7	- 62.7
Cereal crops (%)	39.2	64.6	+81.3
Meadows (%)	8.30	6.7	- 5.1
Hedgerows (%)	6.4	6.3	- 0.3
Ditches (%)	2.0	0.6	- 4.5

Tab. 3 – Differences in small mammal abundance in six habitats in 1985 (a) and 2021 (b). Only species preyed in both years were considered. Abundance is normalized on frequency of night traps*number of traps. / Differenze nell’abbondanza di piccoli mammiferi in sei habitat nel 1985 (a) e nel 2021 (b). Sono state considerate solo le specie predate in entrambi gli anni. L’abbondanza è normalizzata sulla frequenza delle trappole notturne*numero di trappole.

	Marshes		Woodland		Hedgerows		Meadows		Ditches		Poplar	
	a	b	a	b	a	b	a	b	a	b	*a*	*b*
C. suaveolens	0	0	0.05	0.03	0	0	0.05	0	0	0	0	0
M. glareolus	0.27	0	0.59	0.31	0	0.22	0	0	0	0.03	0	0
M. savii	0.02	0	0.02	0	0.11	0	0.07	0.01	0	0.07	0.12	0
A. sylvaticus	0.02	0	0.46	0.53	1.11	0.2	0.76	0.06	0.33	0.13	0.59	0.17
M. minutus	0	0	0	0	0	0	0	0	1.56	0.03	0	0

The author hypothesized that the amount of habitat suitable for harvest mice is limited so that surviving populations are more vulnerable to predation; on the other hand, the clearing of waterside vegetation and a resulting increase in predation have led to a sharp decline of the Water Vole *Arvicola amphibious* during the 20th century (Mate *et al*., 2014). Although the water vole was not a common prey, its importance in owl diet would, nevertheless, be expected to have decreased; the absence of any such decrease may then reflect the increased vulnerability to predation resulting from habitat loss (Howes, 1979; Love *et al*., 2001). Therefore, in our study area, it is likely that concurrent effects of disappearance of marshes, reduction of ditches and alteration of riparian vegetation (Tab. 2) have markedly reduced the average abundance of harvest mouse, but small surviving population were exploited by the log eared owl, able to feed opportunistically on locally suitable trophic sources.

In Tab. 2, we show habitat changes that occurred from 1985 to 2021 around the roosts; analyses were carried out on a 320-ha circle area, adopting an average foraging radius from the literature. In 38 years, the surface of intensive crops, mainly maize and soybeans, strongly increased by 81.3 ha while poplar groves and meadows, which are more stable agro-ecosystems, decreased by 62.7 and 5.1 hectares, respectively. Significant changes also affected natural ecosystems as marshes, starting with wetlands that have completely lost their original surface area of 24.6 ha in 1985, partially converted to natural forests totaling 16.0 ha in 2021. In line with the agricultural rationalization of the area, ditches were also reduced by 4.5 ha, as were hedgerows, although the loss was partially compensated for by new plantings made by farmers and the Nature Reserve with specific European funding (Regulations CEE 2078/78 and 2080/92). In summary, the data in Tab. 2 describe a context of marked change, both in agricultural areas, where stable agro-ecosystems (poplar groves and meadows) are being replaced by intensive cultivation, and in natural areas, where marshes, ditches and hedgerows are decreasing sharply, only partly compensated by their transformation into natural woodland or by new reforesting.

The abundance of small mammals preyed upon by long-eared owls in 1985 and 2021 is reported in Tab. 3; the richness of prey communities and abundance of populations in marshes, poplar groves, and meadows fell to 0 or decreased as a response to the vanishing or reduction of habitats. Richness has increased in the ditches, but the current abundance of wood mouse and harvest mouse, the dominant species in 1985, is very low, as is the abundance of the new species that have colonized this habitat (Tab. 3); in hedgerows, bank vole is currently the dominant species while pine's vole disappeared and wood mouse abundance fall from 1.11 to 0.2. The forest prey community seems to have changed the least between 1985 and 2021; only pine's vole disappeared, while the abundance of dominant species is similar (bank vole) or slightly increased (wood mouse).

In summary, the data in Tab. 3 describe a general decline in community richness and population abundance in all habitats, consistent with the reduction in habitat area that has occurred over time. Between 1985 and 2021, many species in many habitats have disappeared or greatly reduced their abundance (Tab. 3); pine's vole disappeared form marshes, woodlands, hedgerows and poplar groves and the lesser white toothed shrew from meadows. The abundance of the wood mouse, the most important prey and the most common species in 1985 (Canova, 1989) decreased from 92% in meadows to 0.61%, and harvest mouse abundance fell from 1.56 to 0.03 in ditches. Only the bank vole has extended its range of habitats, colonized hedgerows and ditches, and maintains relatively high densities even in woodland (Tab. 3).

CONCLUSIONS

Our study is limited by the scarcity of samples and the lack of an experimental design, but, as previously observed by Balestrieri *et al*. (2019) and Achille *et al*. (2024), for several owl species, the data seem to point to environmental changes caused by agricultural activities as a factor behind the major changes in the diet of the long-eared owl.

The long-eared owl is a generalist predator, but compared to other lowland owls, it is a stenophagous and perhaps selective species, at least with respect to *Sorecinae* and *Crocidurinae*. Consequently, it is not a useful species for detecting population trends or changes over time in the abundance of particular prey categories, such as insectivores; they may be low in diet regardless of their abundance or accessibility. The importance of prey accessibility, regardless of prey abundance, has been highlighted by Taylor *et al*. (2003), Torre *et al*. (2015), and more recently by Achille *et al*. (2024) for more euryphagous species, such as the barn owl *Tyto alba*. The complex of environmental variations induced by anthropogenic and natural factors in our study area may have resulted in the increased accessibility of highly fragmented populations of the harvest mouse and, hence, unusually high predation pressure by the long-eared owl. This may have an additive and detrimental effect on a species that is already rare and is decreasing in a large part of its distributional range.

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REFERENCES

Achille G., Gafta D., Szabó C., Canzian F. & Polini N., 2024 – Dietary shift in a barn owl (*Tyto alba*) population following partial abandonment of cultivated fields (central Apennine hills, Italy). *Animals*, 14: 2562.

Aschwanden J., Birrer S. & Jenni L., 2005 – Are ecological compensation areas attractive hunting places for kestrels *Falco tinnunculus* and long-eared owls *Asio otus*? *Journal fur Ornithologie*, 146: 279-286.

Balestrieri A., Gazzola A., Formenton G. & Canova L., 2019 – Long-term impact of agricultural practices on the diversity of small mammal communities: a case study based on owl pellets. *Environmental Monitoring and Assessment*, 191: 725.

Bertolino S., Ghiberti E. & Perrone A., 2011 – Feeding ecology of the long-eared owl (*Asio otus*) in northern Italy: is it a dietary specialist? *Canadian Journal of Zoology*, 79: 2192-2198.

BirdLife International, 2021 – European Red List of Birds. *Publications Office of the European Union*, Luxembourg.

Birrer S., 2009 – Synthesis of 312 studies on the diet of the long-eared owl *Asio otus*. *Ardea*, 97: 615-624.

Brichetti P., Rubolini D., Galeotti P. & Fasola M., 2007 – Recent declines in urban Italian Sparrow *Passer (domesticus) italiae* populations in northern Italy. *Ibis*, 150: 177-181.

Cannata G., 2014 – Spreco alimentare: una migliore efficienza della filiera agricola. *Ecoscienza*, 5: 26-27.

Canova L., 1989 – Influence of snow cover on prey selection by Long-eared Owls *Asio otus*. *Ethology Ecology and Evolution*, 1: 367-372.

Canova L., 1992 – Distribution and habitat preference of small mammals in a biotope of the North Italian plain. *Bollettino di Zoologia*, 59: 417-421.

Canova L., Yingmei Z. & Fasola M., 1999 – Estimating fresh mass of small mammals in owl diet from cranial measurements in pellets remains. *Avocetta*, 23: 37-41.

Cecere F. & Vicini L., 2000 – Micromammals in the diet of the Long-eared Owl (*Asio otus*) at the W.W.F.'s Oasi San Giuliano (Matera, South Italy). *Hystrix*, 11: 3-13.

Chaline J., 1974 – Les proies des rapaces. *Doin Editeurs*, Paris.

Coates P. S., Brussee B. E., Howe K. B., Fleskes J. P., Dwight I. A., Connelly D. P., Meshriy M. G. & Gardner S. C., 2017 – Long-term and widespread changes in agricultural practices influence ring-necked pheasant abundance in California. *Ecology and Evolution*, 7: 2546-2559.

CREA, 2016 – Piano degli interventi di incremento dell'efficienza organizzativa ed economica, finalizzati all'accorpamento, alla riduzione e alla razionalizzazione delle Strutture. <https://www.crea.gov.it/documents/20126/184841/A_dec_214_9_2016.pdf>.

Darinot D., 2016 – The harvest mouse (Micromys minutus Pallas, 1771) as prey: a literature review. *Folia Zoologica*, 65: 117-134.

de la Peña N. M., Butet A. & Delettre Y., 2003 – Response of the small mammal community to changes in western French agricultural landscapes. *Landscape Ecology*, 18: 265-278.

Di Palma M. G. & Massa B., 1981 – Contributo metodologico per lo studio dell'alimentazione dei rapaci. In: Atti I° Convegno Italiano di Ornitologia. Farina A. (ed.). *Museo Storia Naturale della Lunigiana*. (pp. 69-76).

Filippini S., 2003 – Adozione di stimatori per la valutazione dell'abbondanza di popolazioni di topo selvatico Apodemus sylvaticus e arvicola rossastra *Clethrionomys glareolus*: un approccio empirico. *Università di Pavia*, Pavia.

Galeotti P. & Canova L., 1994 – Winter diet of long-eared owl (*Asio otus*) in the Po plain (Northern Italy). *Journal of Raptor Research*, 28: 265-268.

Garcia Gonzales A. & Cervera Orti F., 2001 – Notas sobre la variación estacional y geográfica de la dieta del búho chico *Asio otus*. *Ardeola*, 48: 75-80.

Gaudenzi G., 1995 – Demografia e dispersione di topo selvatico *Apodemus sylvaticus* e arvicola rossastra *Clethryonomys glareolus* in ambienti boschivi e arbustivi della pianura irrigua lodigiana. *Università di Pavia*, Pavia.

Green R., Harley M., Spalding M. & Zöckler C., 2001 – The impacts of climate change on wildlife. *UNEP World Conservation Monitoring Centre*, Cambridge.

Hagemeijer E. J. M. & Blair M. J., 1997 – The EBCC atlas of European breeding birds: their distribution and abundance. *T. and A.D. Poyser*, London.

Harris S., 2008 – History, distribution, status and habitat requirements of the Harvest Mouse (*Micromys minutus*) in Britain. *Mammal Review*, 9: 159-171.

Haug E. A. & Oliphant L. W., 1990 – Movements, activity patterns, and habitat use of the burrowing owls in Saskatchewan. *Journal of Wildlife Management*, 54: 27-35.

Hole D. G., Whittingham M. J., Bradbury R. B., Anderson G. Q. A., Lee P. L. M., Wilson J. D. & Krebs J. R., 2002 – Agriculture: widespread local house sparrow extinctions. *Nature*, 418: 931.

Holm S., 1979 – A simple sequential rejective multiple test procedure. *Scandinavian Journal of Statistics*, 6: 65-70.

Howes C. A., 1979 – A review of the food and mortality of Water Voles in Yorkshire. *The Naturalist*, 104: 71-74.

Jackson P. & Cresswell W., 2017 – Factors determining the frequency and productivity of double brooding of Barn Owls *Tyto alba*. *Bird Study*, 64: 353-361.

Korpimäki E., 1992 – Diet composition, prey choice, and breeding success of Long-eared Owls: effects of multiannual fluctuations in food abundance. *Canadian Journal of Zoology*, 70: 2373-2381.

Lehikoinen A., Ranta E., Pietiäinen H., Byholm P., Saurola P., Valkama J., Huitu O., Henttonen H. & Korpimäki E., 2011 – The impact of climate and cyclic food abundance on the timing of breeding and brood size in four boreal owl species. *Oecologia*, 165: 349-359.

Love R. A., Webon C., Glue D. E. & Harris S., 2001 – Changes in the food of British barn owls (*Tyto alba*) between 1974 and 1997. *Mammal Review*, 30: 107-129.

Mason C. F., 2006 – Avian species richness and numbers in the built environment: can new housing developments be good for birds? *Biodiversity and Conservation*, 15: 2365-2378.

Mate I., Barrull J., Gosálbez J., Ruiz-Olmo J. & Salicrú M., 2014 – The role of the southern water vole Arvicola sapidus in the diet of predators: a review. *Mammal Review*, 45: 30-40.

Mikkola H., 1983 – Owls of Europe. *A.D. and T. Poyser Ltd.*, Staffordshire.

Milana G., Luiselli L. & Amori G., 2018 – Forty years of dietary studies on barn owl (*Tyto alba*) reveal long term trends in diversity metrics of small mammal prey. *Animal Biology*, 68:129-146.

Milligan S., Holt W. & Lloyd R., 2009 – Impacts of climate change and environmental factors on reproduction and development in wildlife. *Philosophical Transactions of the Royal Society B*, 364: 3313-3319.

Mohring B., Henry P.Y., Jiguet F., Malher F. & Angelier F., 2021 – Investigating temporal and spatial correlates of the sharp decline of an urban exploiter bird in a large European city. *Urban Ecosystems*, 24: 501-513.

Murgui E. & Macias A., 2010 – Changes in the House Sparrow Passer domesticus population in Valencia (Spain) from 1998 to 2008. *Bird Study*, 57: 281-288.

Neyens T., Petrof O., Faes C., Vandenrijt W., Ulenaers P., Artois T., Beenaerts N. & Evens R., 2023 – Winter agri-environment schemes and local landscape composition influence the distribution of wintering farmland birds. *Global Ecology and Conservation*, 45: e02533.

Nilsson I. N., 1981 – Seasonal changes in food of the long-eared owl in southern Sweden. *Ornis Scandinavica*, 12: 216-223.

PanEuropean Common Bird Monitoring Scheme, 1980 – European indicators. <https://pecbms.info/trends-and-indicators/indicators/>.

Perrow M. R. & Jowitt A. J. D., 1995 – What future for the harvest mouse? *British Wildlife*, 6: 356-365.

Riethmuller G., 2021 – Calculating harvesting losses. <https://www.agric.wa.gov.au/harvesting/calculating-harvesting-losses>.

Rigal R., Dakos V., Alonso H. & Devictor V., 2023 – Farmland practices are driving bird population decline across Europe. *Proceedings of the National Academy of Sciences of the United States of America*, 120: E2216573120.

Robinson R. A., Siriwardena G. M. & Crick H. Q. P., 2005 – Size and trends of the house sparrow *Passer domesticus* populations in Great Britain. *Ibis*, 147: 552-562.

Rubolini D., Pirovano A. & Borghi S., 2003 – Influence of seasonality, temperature and rainfall on the winter diet of the long-eared owl, *Asio otus*. *Folia Zoologica*, 52: 67-76.

Schmidt E., 1973 – Die ernaehrung der Waldohreule (*Asio otus*) in Europa. *Aquila*, 80: 221-238.

Shao M. & Liu N., 2006 – The diet of the long-eared owls, *Asio otus*, in the desert of northwest China. *Journal of Arid Environment*, 65: 673-676.

Sharikov A. & Makarova T., 2014 – Weather conditions explain variation in the diet of Long-eared Owl at winter roost in central part of European Russia. *Ornis Fennica*, 91: 100-107.

Sharikov A. V., Makarova T. V. & Ganova E. V., 2014 – Long-term dynamics of long-eared owls *Asio otus* at a northern winter roost in European Russia. *Ardea*, 101: 171-176.

Spadetto L., Gomez-Ramírez P., Zamora-Marín J. M., León-Ortega M., Díaz-García S., Tecles F., Fenoll J., Cava J., Calvo J. F. & García-Fernández A. J., 2024 – Active monitoring of long-eared owl (Asio otus) nestlings reveals widespread exposure to anticoagulant rodenticides across different agricultural landscapes. *Science of the Total Environment*, 918: 170492.

Stanton A., Morrissey C. A. & Clark R. G., 2018 – Analysis of trends and agricultural drivers of farmland bird declines in North America: a review. *Agriculture, Ecosystems & Environment*, 254: 244-254.

Tablado Z., Fauchald P., Mabille G., Stien A. & Tveraa T., 2014 – Environmental variation as a driver of predator-prey interactions. *Ecosphere*, 5: 164.

Taylor I., 2003 – Barn owls: predator–prey relationships and conservation. *Cambridge University Press*, Cambridge.

Tome D., 1991 – Diet of the long-eared owl (*Asio otus*) in Yugoslavia. *Ornis Fennica*, 68: 114-118.

Tome D., 2003 – Functional response of the Long-eared Owl (*Asio otus*) to changing prey numbers: a 20-year study. *Ornis Fennica*, 80:63-70.

Torre I., Gracia-Quintas L., Arrizabalaga A., Baucells J. & Díaz M., 2015 – Are recent changes in the terrestrial small mammal communities related to land use change? A test using pellet analyses. *Ecological Research*, 30: 813-819.

Tulis F., Baláž M., Obuch J. & Šotnár K., 2015 – Responses of the long-eared owl *Asio otus* diet and the numbers of wintering individuals to changing abundance of the common vole Microtus arvalis. *Biologia*, 70: 667-673.

Vecsernyés F., 2020 – Autumn habitat selection of the harvest mouse (*Micromys minutus* Pallas, 1771) in a rural and fragmented landscape. *Revue Suisse de Zoologie*, 126: 111-125.

White T., 2008 – The role of food, weather and climate in limiting the abundance of animals. *Biological Reviews of the Cambridge Philosophical Society*, 83: 227-248.

Wijnandts H., 1984 – Ecological energetics of the long-eared owl (*Asio otus*). *Ardea*, 72: 1-92.

Wotton S. R., Field R., Langston R. H. W. & Gibbons D. W., 2002 – Homes for birds: the use of houses for nesting by birds in the UK. *British Birds*, 95: 586-592.

Zimmerman K., 1963 – Kleinsduger in der Beute von Waldohreule bei Berlin. *Beitrage Vogelkunde*, 9: 59-69.

Zmihorski M., Romanowski J. & Chylarecki P., 2012 – Environmental factors affecting the densities of owls in Polish farmland during 1980-2005. *Biologia*, 67: 1204-1210.