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AN UNUSUAL HIGH PREY RICHNESS OF SMALL MAMMALS IN TAWNY OWL (*STRIX ALUCO*) PELLETS: A COMPARISON WITH ITALIAN DATA-SETS SUGGESTS A ROLE OF HABITAT HETEROGENEITY WHEN CONTROLLING FOR SAMPLE SIZE

Abstract - P. Crescia, V. Ferri, S. Celletti, C. Soccini, C. Battisti, *An unusual high prey richness of small mammals in Tawny Owl (*Strix aluco*) pellets: a comparison with Italian data-sets suggests a role of habitat heterogeneity when controlling for sample size.*

We report a case study of high prey richness of small mammals recorded in Tawny Owl (*Strix aluco*) pellets from a site of Northern Latium, the highest known for Italy (also after normalization with sample size). We compared our data to a large set of available literature, obtaining a significant correlation between prey species and sample size. However, when controlling for sample size, habitat heterogeneity could explain the high species richness recorded. Our data evidenced a trophic generalism of Tawny Owl in suburban heterogenous landscapes. Nevertheless, we highlighted as only a comparison among normalized data may exclude artifact due to sampling effect. Further research are necessary to test the role of biogeographical factors on small mammal communities as prey, as yet observed for other Strigiformes..

Key words - diet diversity, generalism, habitat heterogeneity, Latium (Italy), prey composition, sample size, Tawny Owl

Riassunto - P. Crescia, V. Ferri, S. Celletti, C. Soccini, C. Battisti, *Una inusuale alta ricchezza di specie-preda di piccoli mammiferi in borre di Allocco (*Strix aluco*): una comparazione con data-sets suggerisce un ruolo della eterogeneità di habitat, dopo normalizzazione dei dati.*

Viene riportato un caso di elevata ricchezza di specie-preda (piccoli mammiferi: insettivori, roditori e chirotteri) rinvenute in borre di Allocco (*Strix aluco*) da un sito del Lazio settentrionale, il più alto noto per l'Italia (anche dopo normalizzazione dei dati). Abbiamo confrontato i nostri risultati con un ampio set di letteratura disponibile, ottenendo una correlazione significativa tra ricchezza di specie predate e dimensione del campione. Tuttavia, dopo normalizzazione dei dati, l'eterogeneità dell'habitat potrebbe comunque spiegare l'elevata ricchezza di specie registrata, evidenziando un generalismo trofico dell'Allocco in mosaici ambientali suburbani. Pertanto, si sottolinea come solo un confronto tra dati normalizzati possa consentire di escludere possibili artefatti dovuti all'effetto delle dimensioni del campione. Ulteriori ricerche saranno necessarie per testare il ruolo dei fattori biogeografici sulle comunità di piccoli mammiferi predate, come osservato per altre specie di Strigiformi.

Parole chiave - allocco, dimensione del campione, diversità della dieta, eterogeneità ambientale, generalismo, Lazio

Introduction

Strigiformes diversify their diet both in relation to intrinsic species-specific characteristics (e.g., trophic specialization), and as a opportunistic response to extrinsic factors (e.g., types of habitats, environmental heterogeneity and disturbances in the surrounding; Sarà, 1990; Alivizatos *et al.*, 2005).
Considering only the mammal component obtained through the pellet analysis, while the Barn Owl (*Tyto alba*) shows a high trophic generalism including in the diet a wide spectrum of prey (about 10 taxa per site in central Italy: Contoli, 1980; Aloise *et al.*, 1990; Prete *et al.*, 2012; Di Bagno *et al.*, 2020:> 12 in northern Italy: Bon *et al.*, 1993; Mazzotti & Bortolotti, 1999), also due to its preferences for differently anthropized mosaic habitats (Contoli & Di Russo, 1985; Calvario *et al.*, 1992), other owls show a higher specialization due to their linkage with less spatially heterogeneous contexts such as forests or agro-forestry mosaics where the number of suitable prey species may be lower. For example, the Long-eared Owl (*Asio otus*) shows a selectivity in diet, with consequent reduction in the number of prey species per site (≤10; Village, 1981; Ýmihorski & Osojca, 2006; for Italy: Plini, 1986; Casini & Magnani, 1988; Malavasi, 1995; Siracusa *et al.*, 1996; Manganaro, 1997; Simmi *et al.*, 1998, Bruni, 2002; Trotta, 2010) with exceptions represented for roosts where a high number of owls accumulate prey (Castioni *et al.*, 1998). Similarly, Tawny Owl (*Strix aluco*), mainly linked to forests, mosaic and urban parks, shows a less number of prey when compared to Barn Owl (Sarà & Massa, 1985; Galeotti, 1990; Sarà, 1990; Ranazzi *et al.*, 1999; Manganaro *et al.*, 2000; Gaggi & Paci, 2009, Paci, 2020).
In this short note we report a case of high number of small mammal prey species obtained from a single sampling site of Tawny Owl (*Strix aluco*), the highest known for Italy. Since the number of recorded spe-

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cies is correlated to the sample size (considered as a non-ecological effect; Hill *et al.*, 1994), we compared our data to a large set of available literature, carrying out a correlation between prey species and sample size. We hypothesize that, once controlling for sample size, habitat heterogeneity could explain the high species richness recorded.

Materials and Methods

The pellets were collected at a nesting site located on a cave dug into the biocalcarenite and biocalcirudite ('macco') cliff ('Antro di Polifemo'; see Chiocchini & Potetti, 1998) near Tarquinia (Nothern Latium, central Italy; 42° 15'26.4" N 11° 45'20.6" E).

Within a radius of 1 km from the site, an environmental mosaic develops with the Tarquinia historic center of medieval origin and suburban areas (28.10% in cover), agricultural areas with crop lands (56.67%), forest mosaics dominated by *Quercus ilex/Quercus cerris* and surrounding Mediterranean scrub with *Phyllirea media*, *Pistacia lentiscus*, *Myrtus communis*, *Arbutus unedo* (8.82%), river streams of different flow rates (riparian vegetation with *Bolboschoenus maritimus*, associated with hygrophitic vegetation (3.86%); orchards and vineyards (2.56%). The area was described as a transitional zone from a Mediterranean to a Temperate bioclimate (Blasi, 1994; further details in Olmi & Zapparoli, 1992).

Pellets were collected around the nest sites from March 2018 to March 2020 without carrying out a seasonal stratification. The individual pellets were broken down by hand and prey items were identified to the lowest possible taxonomical level (Heisler *et al.*, 2016). Osteological remnants (mainly skulls and jaws) were macroscopically identified while teeth and feathers were identified under a stereo microscope at 25x or 50x magnification. The identification was carried out at a specific level, where possible, by comparing undigested remains with a reference collection following Amori *et al.* (2008). Prey numbers were estimated as the minimum number of individuals which we determined according to the same anatomical parts of skulls, jaws and bones for small mammals (McDowell & Medlin, 2009).

Nomenclature of small mammals followed Loy *et al.* (2019).

For each site, we obtained the number of species (S) and the normalized species richness (Margalef index) as Dm=(S-1)/ln(N) (Margalef, 1958), where N was the total number of prey items (details in Magurran, 2004). When not available in the literature, we re-calculated the index from published original data.

We compared number of prey species by Tawny Owl to prey abundance reviewing a representative number of sites for Italy using a bivariate regression analysis (Ordinary Least Squares which assumes the x values are fixed and finds the line which minimizes the squared errors in the y values). To fit the Gaussian response models to ln-transformed species abundances along a gradient, for one or more species we performed a species packing analysis (Gaussian), using as fitted parameters: optimum (average), tolerance (standard deviation) and maximum. The algorithm is the same as for the Gaussian function in the nonlinear regression module: initial estimation of optimum and tolerance based on the weighted average, followed by a nonlinear optimization by the Levenberg-Marquardt method. For statistical analyses we used the PAST software (Hammer, 2001). Alpha level was set at 0.05 level.

Results

Analyzing 284 pellets, we obtained 3273 osteological remains (skulls, jaws) corresponding to 1468 specimens of homeotermic vertebrates. Among them, we obtained 1382 specimens of small mammals belonging to 15 taxa (12 of terrestrial mammals: Soricomorpha and Rodentia, n = 1377; three of bats: Chiroptera, n = 5; Tab. 1). Normalized richness (Margalef index) was Dm=1.936, the higher when compared to a large number of Italian sites (Tab. 2).

When comparing the prey abundance (ln-transformed) to species number (data from Italian literature; only small mammals), we observed as the two variables are highly correlated (linear regression: S = 1.392 Ln(N) + 1.087; R^2 = 0.35, p<0.01; Species packing analysis (Gaussian) with better fit line: optimum average: 10.37, tolerance standard deviation: 5.24; maximum: 13.67; Fig. 1).

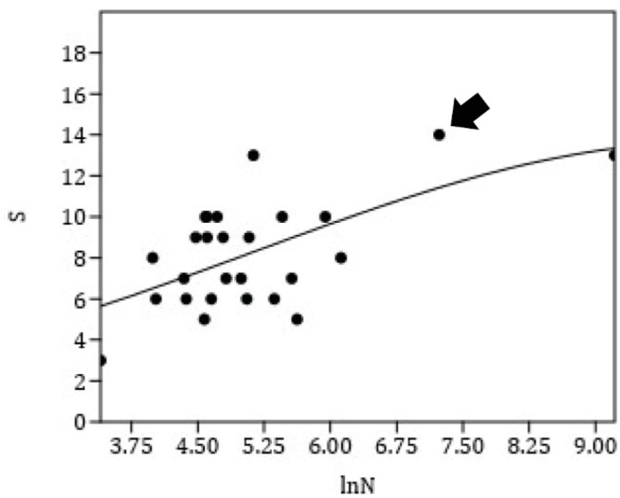

Figure 1. Species packing analysis (Gaussian) with better fit line. Arrow shows the study site.

Table 1. Small mammals prey species in Tawny Owl (*Strix aluco*) pellets. N: number of specimens; Fr%: percentage frequency.

Prey species	**N**	**Fr%**
Soricomorpha		
Suncus etruscus (Savi, 1822)	47	3.40
Crocidura suaveolens (Pallas, 1811)	109	7.89
Crocidura leucodon (Hermann, 1780)	114	8.25
Sorex samniticus Altobello, 1826	8	0.58
Rodentia		
Muscardinus avellanarius Linnaeus, 1758	2	0.14
Arvicola italicus Savi, 1839	16	1.16
Microtus savii (de Sélys Longchamps, 1838)	85	6.15
Apodemus sylvaticus (Linnaeus, 1758)	272	19.68
Apodemus sylvaticus vel *flavicollis*	21	1.52
Mus domesticus Schwarz and Schwarz, 1943	654	47.32
Rattus norvegicus (Berkenhout, 1769)	11	0.80
Rattus rattus (Linnaeus, 1758)	38	2.75
Chiroptera		
Myotis spp.	1	0.07
Eptesicus serotinus (Schreber, 1774)	3	0.22
Rhinolophus ferrumequinum (Schreber, 1774)	1	0.072
Total (small mammals)	1382	100
Aves spp.	86	
Total prey	1468	

Table 2. Number of specimens recorded (N), number of small mammal taxa (taxa: terrestrial mammals: Soricomorpha and Rodentia, and bats, Chiroptera) and Margalef index (Dm), recorded in selected published papers about Tawny Owl (*Strix aluco*) pellets from Italy (in chronological order; study site has been reported for each reference).

Ref	**Site**	**N**	**taxa**	**Dm**
Contoli & Sammuri, 1978	Belaggio (Grosseto)	381	10	1.514
Arcà, 1980	Carbognano (Viterbo)	261	7	1.078
Arcà, 1980	Bomarzo (Viterbo)	77	7	1.381
Arcà, 1980	Licenza (Rome)	161	9	1.574
Gerdol *et al.*, 1982	Carso (Trieste)	10055	13	1.302
Pedrini, 1982	Rumo (Trento)	112	10	0.081
Fraticelli, 1983	Palo laziale (Rome)	30	3	0.588
Sarà & Massa, 1985	Ficuzza (Palermo)	455	8	1.144
Sarà & Massa, 1985	Suburban sites (Palermo)	214	6	0.932
Pinchera, 1987	Rocca di Mezzo (L'Aquila)	100	10	0.090
Debernardi & Patriarca, 1988	La Mandria (Torino)	169	13	0.071
Bertarelli *et al.*, 1992	Concordia s. Secchia (Modena)	100	9	1.737
Boldreghini & Matteucci, 1993	Predappio (Forlì)	56	6	1.242
Montanari, 1995	Agazzano (Piacenza)	98	10	0.092
Capizzi & Luiselli, 1996	Settebagni (Rome)	157	6	0.989
Siracusa *et al.*, 1996	Etna Mt. (Catania)	105	6	1.074
Capizzi & Luiselli, 1998	S. Rossore (Pisa)	54	8	1.755
Capizzi & Luiselli, 1998	Ronciglione (Viterbo)	88	9	1.787
Bon & Bazzani, 1999	Cà Tron (Treviso)	124	7	1.245
Ranazzi *et al.*, 1999	Castelporziano (Rome)	277	5	0.711
Giovo in Capizzi, 2000	Tarvisio (Udine)	234	10	1.650
Ricci *et al.*, 2003	Campo di Giove (L'Aquila)	79	6	1.144
Ricci *et al.*, 2003	Palena (Chieti)	120	9	1.671
Costantini *et al.*, 2008	Rome	97	5	0.874
Giannotti *et al.*, 2009	Astroni (Naples)	147	7	1.202
This study	Tarquinia (Viterbo)	1382	15	1.936

Discussion

Our data confirm that Tawny Owls are trophic generalists that feed opportunistically on small mammals in a variety of habitats (Contoli, 1988; Zmihorski *et al.*, 2011). However, besides the ecological (intrinsic) characteristics of the species, habitat heterogeneity may be an additional extrinsic factor explaining their high prey richness (Sarà, 1990; habitat heterogeneity is a driver of species richness: Cramer & Willig, 2005; for mammals: Fløjgaard *et al.*, 2011). The local fine-grained heterogeneity of our study site, which includes suburban areas, forest contexts, crop lands, ecotones, and wet habitats, may explain the high number of prey taxa recorded. Therefore the reduction in the number of prey species in urban environments can be compensated by the high availability of small mammal species in different habitats (Sarà & Massa 1985; Galeotti, 1989).

However, we believe that, before attributing patterns in data outputs to ecological processes (in our case: extrinsic habitat heterogeneity or intrinsic traits of the species as generalism/opportunism), it is important to verify that the data outputs are not artifacts. Sample size effect should be treated as a null hypothesis, and only once it is rejected, can other hypotheses (intrinsic or extrinsic ecological factors; see Hill *et al.*, 1994) be considered. A comparison of our data to Italian pellet datasets obtained for Tawny Owls from other sites shows that the number of prey species is significantly correlated to sample size, although the data showed a high variance (low coefficient of determination, R^2).

However, when controlling for sample size using a normalized metric as the Margalef index, we observed that our site shows the highest value. In this regard, both sample size and local habitat heterogeneity may explain our data.
In conclusion:

(i) Our case study shows that the Tawny Owl is a highly generalist, opportunistic and plastic species, with an euryphagia likely comparable to the Barn Owl (see Gerdol *et al.*, 1982; Capizzi & Luiselli, 1998), typical of urbanization gradients (Galeotti *et al.*, 1991; Grzędzicka *et al.*, 2013; Gryz & Krauze-Gryz, 2019). In this regard, we suggests that the lower trophic diversity observed in the Tawny Owl, compared to the more generalist Barn Owl (Contoli, 1988), may also be attributed to the difficulty of obtaining an adequate number of osteological remains for analysis. In contrast, the latter species' resting and nesting sites (e.g. abandoned farmhouses) are easily identifiable, facilitating the collection of very large samples spanning a wide time range (Avenant, 2005);

(ii) Only a comparison of normalized richness data obtained for different Strigiformes species on a representative number of sites will allow us to clarify the different role of extrinsic (linked to environment and environmental heterogeneity) and intrinsic factors (trophic generalism of the species), excluding artifact resulting from sample size;

(iii) Regarding the relationship between the number of species and ln-transformed sample size, other predictors should be considered, as, for example, biogeographical ones associated with the 'peninsula effect' (see for *Tyto alba*: Battisti *et al.*, 1997).

Author contributions

PC, VF, SC, CS sampled owl pellets and carried out the experimental part of data collection; VF and CB had the idea of this research; CB dealt with the study design and data analysis. All the authors drafted the manuscript, carried out the bibliographic searches, read, reviewed and approved the final manuscript.

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