RESEARCH ARTICLES
ОРИГИНАЛЬНЫЕ СТАТЬИ

THE WINTER DIET OF THE RARE *TYTO ALBA* IN CONTRAST TO *ASIO OTUS* ON CRIMEA PENINSULA

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The range of *Tyto alba* overlaps with that of *Asio otus* in a large part of the Holarctic. Both species are adapted to open-area hunting and prey upon similar species. In contrast to *A. otus*, data about the diet of *T. alba* on Crimea and surroundings are extremely scarce. Our study aimed to describe the prey spectrum of *T. alba* and evaluate at what extant its diet overlaps to that of *A. otus*. We evaluated diets based on 48 pellets of *T. alba* and 88 of *A. otus* collected from January to March 2018 in the Western part of the Crimea Peninsula. Simultaneously, we assessed the availability of small mammal prey by installing 150 spring-loaded bar mousetraps around the collection sites. Small mammals were the main prey in the diet of *T. alba* and *A. otus* (99.2% and 100% of all individuals in pellets). The most consumed species of both species was *Microtus socialis* (52.3% and 74.4% of all individuals). The second most consumed species of *T. alba* was *Crocidura leucodon,* an endangered species in Crimea. The diet of *T. alba* was more diverse than that of *A. otus* (Shannon diversity Index: 1.1 and 0.76, Simpson Index: 0.51 and 0.31, respectively). However, their diets overlapped widely (Pianka's index = 0.94). The frequency of mammalian prey in traps correlated moderately with that in *A. otus* pellets ($r_s = 0.5$, $p < 0.2$), and it deviated from the frequency of mammalian prey in *T. alba* pellets ($r_s = -0.05$, $p < 0.9$). The presence of the endangered *C. leucodon* in the diet of *T. alba* reinforce the utility of this predator species as a tool to detect threatened or rare small mammals that are not caught by traps and to increase information about their geographical distribution.

Key words: Aves, Bicoloured shrew, diet diversity, dietary overlap, Social vole, Strigiformes

Introduction

Tyto alba (Scopoli, 1769) is a widespread polytypic species. It breeds in South, Central and North America, Africa, except the Sahara, Mediterranean, South Asia, Australia and islands. In Europe, it occupies territories from the Atlantic coast to western Latvia, Belarus in the north and to the Black sea coast in the south (Zubkov, 2005; Bashta & Bokotey, 2009). In Ukraine, it is a rare species with a breeding population estimated in 30 pairs, most of which are in West Ukraine (Bashta & Bokotey, 2009). Some authors have also observed breeding pairs and single individuals in the Pre-Caucasian region of the Russia Federation (Zubkov, 2005; Ilyukh & Khokhlov, 2010). On the Crimea Peninsula, a few migrating and wintering individuals and breeding pairs have been registered in the XXI century (Prokopenko & Beskaravayny, 2009; Kucherenko et al., 2017).

The range of *T. alba* is overlapped to that *Asio otus* (Linnaeus, 1758) in a large part of the Holarctic (Leader et al., 2010). Both species have a nocturnal and crepuscular activity, and they are adapted to open-area hunting and prey upon similar animals. However, they also have some ecological differences. *Asio otus* breeds in forest remnants in the vicinity of open landscapes or in the forest belts among arable fields, locating nests in trees, where it uses old nests of Corvidae, and hunting both from perches and in flight. In winter, individuals of *A. otus* form communal roosts. *Tyto alba* breeds in farmland with scattered copes and locates nests in natural (e.g., tree holes) or artificial (e.g., nest boxes, barns) cavities. In winter, individuals of *T. alba* tend to roost alone. Understanding how top predators are trophically related is essential to establish prey-based conservation strategies.

Some recent studies provide detailed information about the ecology of *A. otus* on Crimea, primarily on the characteristic of winter roosts and on the trophic relationships (Tovpinets & Evstaf'ev, 2013; Kucherenko & Kalinovsky, 2018). In contrast, information about the trophic ecology of *T. alba* on Crimea and surroundings is scarce (e.g. Koshelev & Belashkov, 2002; Prokopenko & Beskaravayny, 2009; Ilyukh & Khokhlov, 2010). This is due to the rarity of this species in the area, which is the reason why this species is in the Red Data Book of the Republic of Crimea (Beskaravayny, 2015).

Our study aimed to describe the prey spectrum of *T. alba* and evaluate at what extant its diet overlaps to that of *A. otus* in an area where they are sympatric in Crimea Peninsula. Moreover, as we found an endangered *Crocidura* species among the prey of *T. alba*, we noted the utility of *T. alba* pellets for detecting threatened small mammals.

Material and Methods

We conducted our research in the Western part of the Crimea Peninsula, an area with open cultivated and uncultivated agricultural land. We collected 48 pellets of *T. alba* in ruined buildings in Saky district (45.327957° N, 33.064789° E) on 12.02.2018 and 14.03.2018 (Fig. 1). On this site, we only observed a single wintering individual of *T. alba*, which perched inside the building. We collected all pellets under this perch. We collected 88 pellets of *A. otus* on 25.01.2018 on a site where owls formed a communal roost. It is located a few kilometres northeast from the wintering site of *T. alba*. Since the pellets of *T. alba* and *A. otus* (Fig. 2) differ considerably in size, we had no doubt about which species the pellets were of.

We analysed only entire pellets (i.e., no broken ends, no fragmentation, no splitting or loosening of pellets), teasing them apart by dry manual dissection (Holt et al., 1987). The pellets only contained remains of mammals and birds. We identified mammalian prey species by comparing the mandibles, craniums (whole or broken) and tibias recovered from pellets with our own bone collection of local mammals, and according to Gromov (1995). In the case of avian prey, we compared feather fragments, large bones (e.g., tarsus) and beaks with plates in field guides (Fesenko & Bokotey, 2002; Svensson, 2010) and with bird skins maintained in the Zoological Museum of V.I. Vernadsky Crimean Federal University. We determined the number of individuals in each pellet by counting the number of the most frequent body element (e.g., number of left or right mandibles or tibiae, number of beaks or presence of feathers) (Yom-Tov & Wool, 1997). If we could not categorically distinguish the body pieces of congeneric species, we combined them within the same genus. To assess the consumed biomass we used literature data about prey weight (Panteleev et al., 1990; Fesenko & Bokotey, 2002; Ronald & Walker, 2005; Kryštufek & Vohralik, 2009).

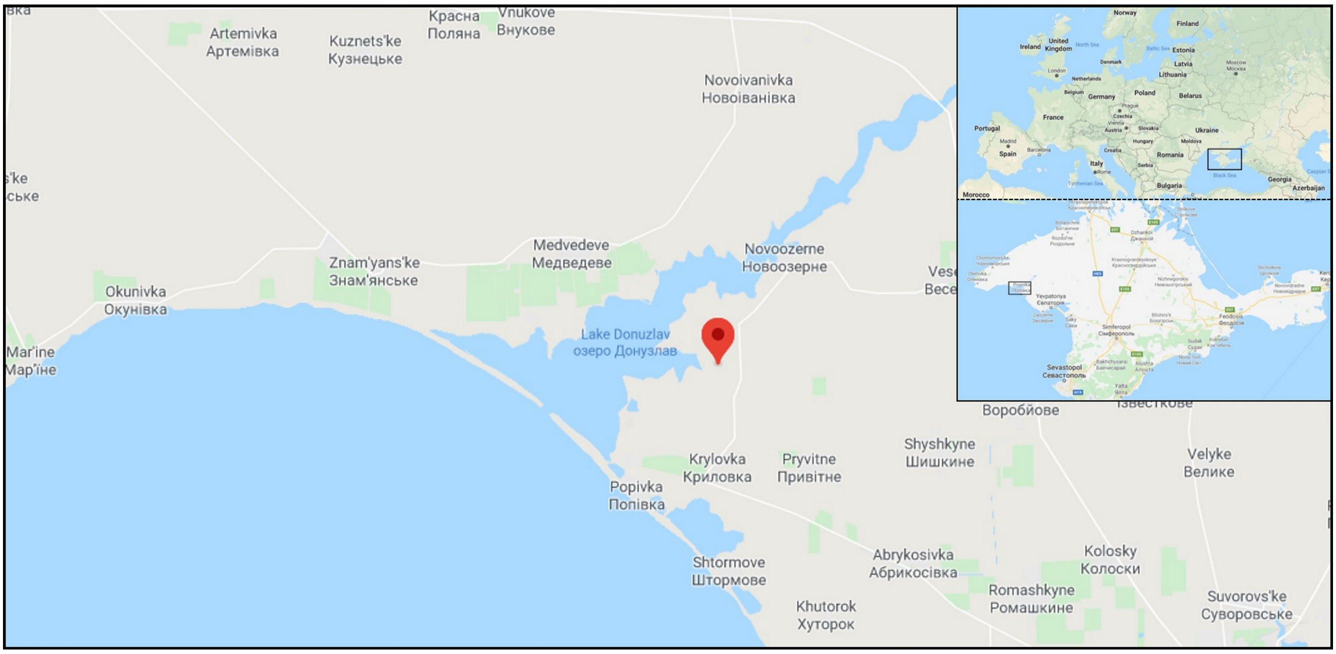

Fig. 1. Study area of the winter diet of *Tyto alba* and *Asio otus* on the Crimea Peninsula. Red dot – both species' pellet collection site.

Fig. 2. Pellets of *Tyto alba* (left) and *Asio otus* (right) collected during winter 2018 in the western part of the Crimea Peninsula.

We measured the size of the pellets of both owl species. It can be useful for identifying both species (at the local level) if only their pellets are found. To estimate the differences in the mean number of individuals per pellet and biomass per pellet between *T. alba* and *A. otus*, we used the *t*-Student test and visual comparison. We used χ^2 to detect differences between the frequencies of the most important genus in pellets of both species.

We also compared the diets of *T. alba* and *A. otus* by estimating two food niche metrics: diet diversity (food breadth) and dietary overlap. We estimated the food diversity of the prey species level by using the antilog of the Shannon index and the Simpson index, as they display the food-niche breadth (Pesenko, 1982; Magurran, 2004). To standardise food diversity for comparison between *T. alba* and *A. otus*, we also calculated food evenness (Alatalo, 1981). To contrast indexes of food diversity, we used the *t*-Student test. We measured the dietary overlap as follow:

$$O_{xy} = \frac{\sum P_{ix} \times \sum P_{iy}}{\sqrt{\sum P_{ix}^2 \times \sum P_{iy}^2}},$$

where O_{xy} – Pianka's measure of niche overlap between species x and species y; P_{ix} – Proportion resource i is of the total resources used by species x; P_{iy} – Proportion resource i is of the total resources used by species y.

To evaluate whether owls consume small mammal prey according to its field availability, we compared the frequency in pellets versus the frequency in field by trapping small mammals. We used two data sources to obtain an approximation to the small mammal availability in the field. First, we derived the field availability of small mammals around the study area from a long-term study on the small mammal fauna in Crimea conducted between 1986 and 2016 (Evstafiev, 2016). To obtain a more refined approximation of the field abundance of small mammals, we conducted small mammal trappings in our study site simultaneously to the pellet collection by using spring-loaded bar mousetraps. On 14–15 March 2018, we established three 50-traps transect-lines across the most typical biotopes (total effort = 150 trap-night). To attract the mammals, we used bread with sunflower oil. We calculated the overall frequency of small mammal species by summing all individuals captured in each transect-line. Since the number of small mammals captured by trapping and the number of prey in pellets refers to relative counts, we used the prey/pellets ratio and prey/traps ratio for comparison. Thus, to infer a congruency between consumption and availability of prey species, we contrast the number of individuals per pellets versus the number of individuals captured per traps (non-functional traps discounted) by using the Spearman correlation (r_s). We conducted all statistical calculations by using PAST software (Hammer et al., 2001).

Results

The pellets of *T. alba* contained 258 individuals belonging to at least eight species (Table 1). We could not categorically assign 20 individuals to either *Mus musculus* Linnaeus, 1758, or *Mus spicilegus* Petenyi, 1882, while possibly *T. alba* preyed upon *M. musculus* too. We combined them into the *M. musculus/spicilegus* complex. The most frequent species in pellets was *Microtus socialis* (Pallas, 1773) reaching about half of all individuals, followed by *Crocidura leucodon* (Hermann, 1780) and *M. spicilegus* (Table 1). The remaining species accounted for about 1% of all individuals. Among the mammalian prey, we also identified a single individual of *Mustela nivalis* Linnaeus, 1766. *Turdus merula* Linnaeus 1758 was the only avian prey identified in pellets of *T. alba*.

Although the number of collected pellets of *A. otus* was almost twice as that of *T. alba*, they contained fewer prey individuals and less species (Table 1). The most frequent species in pellets of *A. otus* was *Microtus socialis*. The remaining species individually accounted for less than 10% of all individuals each. The proportions of biomass of consumed species were very similar to their species ratio in the diet (Table 2).

Table 1. Prey species in pellets of *Tyto alba* (n = 48) and *Asio otus* (n = 88) during the winter 2018 on the Crimea Peninsula and the frequency of small mammals in the field as estimated by live-trapping

Prey	*Tyto alba*		*Asio otus*		trapping	
	Number	Proportion, %	Number	Proportion, %	Number	Proportion, %
Microtus socialis (Pallas, 1773)	135	52.3	166	74.4	5	31.3
Sylvaemus witherbyi (Thomas, 1902)	4	1.6	7	3.1	–	–
Mus musculus Linnaeus, 1758	–	–	10	4.5	8	50.0
Mus specilegus Petenyi, 1882	16	6.2	6	2.7	–	–
Mus musculus/spicilegus	20	7.8	20	9.0	–	–
Cricetulus migratorius (Pallas, 1773)	1	0.4	10	4.5	–	–
Crocidura suaveolens (Pallas, 1811)	12	4.7	4	1.8	3	18.7
Crocidura leucodon (Hermann, 1780)	30	11.6	–	–	–	–
Crocidura suaveolens / leucodon	38	14.7	–	–	–	–
Mustela nivalis Linnaeus, 1766	1	0.4	–	–	–	–
Turdus merula Linnaeus 1758	1	0.4	–	–	–	–
Total	258	100	223	100	16	100

Table 2. The biomass, consumed by *Tyto alba* and *Asio otus* during the winter 2018 on the Crimea Peninsula (48 and 88 pellets respectively)

Prey	Mass, g	*Tyto alba*		*Asio otus*	
		Biomass	Proportion, %	Biomass	Proportion, %
Microtus socialis	23	3105	66.0	3818	76.4
Sylvaemus witherbyi	27	108	2.3	189	3.8
Mus musculus	16	–	–	160	3.2
Mus specilegus	16	256	5.4	96	2.0
Mus musculus/spicilegus	16	320	6.8	320	6.4
Cricetulus migratorius	38	38	0.8	380	7.6
Crocidura suaveolens	8	96	2.0	32	0.6
Crocidura leucodon	8	240	5.1	–	–
Crocidura suaveolens/leucodon	8	304	6.5	–	–
Mustela nivalis	140	140	3.0	–	–
Turdus merula	95	95	2.0	–	–
Total		4702	100	4995	100

Tyto alba produced greater pellets (50.6 ± 3.1 mm length and 28.1 ± 0.7 mm width, n = 24) than *A. otus* (47 ± 1.6 mm length and 18.6 ± 0.4 mm width, n = 20) (Fig. 2). The length differences were not significant, but the width differed considerably (*t*-Student test, $t = 13.8$, $p < 0.05$). The mean number of individuals per pellet differed considerably between both species (Fig. 3): 5.4 ± 0.3 individuals per pellets for *T. alba* (n = 48 pellets) versus 2.3 ± 0.1 prey per pellets for *A. otus* (n = 88 pellets; *t*-Student test, $t = 11.6$, $p < 0.001$). The mean biomass per pellet also differed considerably (Fig. 3): 97.7 ± 5.1 g per pellet, for *T. alba* (n = 48 pellets) versus 53.1 ± 2.2 g per pellet for *A. otus* (*t*-Student test, $t = 9.2$, $p < 0.001$).

The proportion of the most consumed mammalian prey at genus level (*Microtus*, *Sylvaemus*, *Mus* and *Crocidura*) differed significantly ($\chi^2_3 = 69.6$, $p < 0.001$) between the pellets of *T. alba* and *A. otus*.

Tyto alba showed a more diverse diet that *A. otus* (Shannon index: 1.1 vs. 0.76; Simpson index: 0.51 vs. 0.31; evenness: 0.37 vs. 0.36, respectively). Differences in diet diversity were statistically significant: Shannon index, *t*-Student test $t = 2.8$ (df = 401.25, $p < 0.05$); Simpson index, *t*-Student test $t = -3.3$, (df = 399.8, $p < 0.01$). There was a high similarity between the diets of *A. otus* and *T. alba* (Pianka's index = 0.94).

The frequency of mammalian prey in traps correlated moderately with the frequency of mammalian prey in *A. otus* pellets ($r_s = 0.5$, $p < 0.2$) (Fig. 4). The frequency of mammalian prey in traps deviated from the frequency of mammalian prey in the *T. alba* pellets ($r_s = -0.05$, $p < 0.9$).

Discussion

On the study site, small mammals were the primary prey of *T. alba* and *A. otus* during winter reaching 100.0% and 99.2% of all individuals identified in pellets, respectively. *Microtus socialis* formed almost three-quarters and almost half of the individuals consumed by *A. otus* and *T. alba*, respectively. According to literature data, rodents of the genus *Microtus* predominate in the diet of both species in Poland and

Romania (Kitowsky, 2013; Petrovici et al., 2013), Greece (Alivizatos, 1999), and USA (Khalafalla & Iudica, 2010). Possibly, the high consumption of those rodents is due to its higher abundance in the field in many places (e.g., Gromov, 1995; Volkov et al., 2009), increasing the probability that owls find them more often. However, throughout the long-term trapping of small mammals in the steppe on Crimea, the frequency of *M. socialis* was low, reaching only 6.8% of all small mammals captured (Evstafiev, 2016). Moreover, in our catches in the study area, *M. socialis* accounted for only one-third of the captured rodents. Such results agree with the suggestion that owl pellets do not accurately represent the proportion of prey species in the field (Yom-Tov & Wool, 1997). On the other hand, it is also possible that trapping based on both live traps and spring-loaded bar mousetraps might not truly reflect the actual availability of small mammals in the field because that species could differently respond to them. We also have to admit that our trapping effort was overly low to obtain a robust ranking of field abundance of small mammal species. An alternative explanation for the high consumption of *M. socialis* by owls is that possibly this species is much more nocturnal than other rodent species, and so coinciding more fully with the circadian rhythm of *T. alba* and *A. otus*.

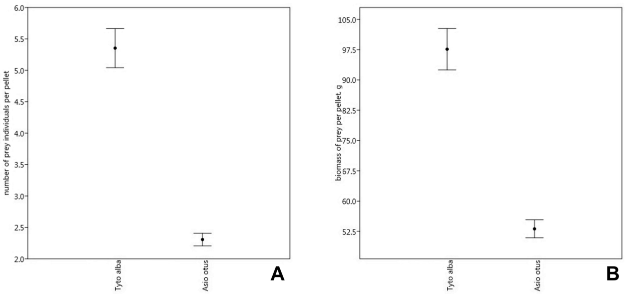

Fig. 3. Prey/pellets (A) and biomass/pellets (B) ratio for *Tyto alba* (n = 48 pellets) and *Asio otus* (n = 88 pellets) during the winter 2018 on the western Crimea Peninsula (dots – mean, «whiskers» – standard errors).

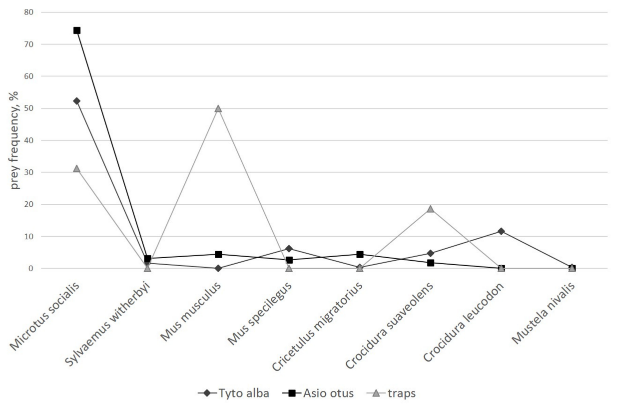

Fig. 4. The frequency of mammal prey species in pellets of *Tyto alba* and *Asio otus* and in the traps during the winter 2018 on the western Crimea Peninsula.

According to our results, *T. alba* preys on a broader range of animals than *A. otus*, and *T. alba* pellets contain a higher number of individuals and biomass compared to *A. otus*. Other authors noted a similar pattern in some other parts of their range (Khalafalla & Iudica, 2010; Petrovici et al., 2013). However, we could not categorically determinate, if *T. alba* preys on *Mus musculus* as their bones were not easily distinguishable from those of *M. specilegus*. Although *A. otus* preys upon *M. musculus* on our study site, the representation in the pellet was low (< 5% of all prey individuals). In a previous study (Tovpinets & Evstaf'ev, 2013), we found that *M. musculus* was the primary prey species of *A. otus* in the steppe of the Crimea (24.3% of all prey individuals), while *Cricetulus migratorius* was less common (6.2%). Such regional variations in diet could be due to difference in prey availability.

Crocidura leucodon was the second most numerous prey (11.6%) on the diet of *T. alba*. On the Crimea Peninsula, *C. leucodon* is an endangered species (Tovpinets, 2015). By regular trapping, conducted during 36 years (1980–2016) in the steppe zone of the Crimea Peninsula, Evstafiev (2016) could capture only 30 individuals of *C. leucodon*. For this reason, it is remarkable that *T. alba* had consumed 30 individuals of *C. leucodon* on our study site. Possibly, this species increases in number during winter within the hunting areas of *T. alba*. Moreover, *C. leucodon* prefers open habitats (Tovpinets, 2015), especially steppes, which make them more vulnerable for predation. It is noteworthy that *A. otus* had not consumed *C. leucodon*, as it is within the size range of their prey. Possibly, *A. otus* was unable to detect *C. leucodon* in the field, or it hunted on areas where that animal was absent.

The presence of an endangered shrew in the pellets of *T. alba* in our study site reinforce the utility of this owl species as tool to detect threatened or rare small mammals that are not caught by traps and to increase information about their geographical distribution (Avery at al., 2005). Our finding represents the most north-western record of *Crocidura leucodon* on the Crimea. On the other hand, the high proportion of one rare prey species in the diet of rare *T. alba* indicates the vulnerability of the ecosystem of the steppe on the Crimea because of the high probability that the loss of one rare species will negatively affect other rare species. On the Crimea, *C. leu-*

codon inhabits the least cultivated steppe areas. So its low abundance can be an indicator of the destruction of the steppe areas.

Overall, the proportion of shrews in the diet of *T. alba* was much higher than in the diet of *A. otus*. *Tyto alba* consumed 80 individuals of two *Crocidura* species accounting for almost a third of all consumed prey. In contrast, *A. otus* preyed upon only four individuals of *Crocidura suaveolens* (Pallas, 1811) accounting for only 2% of the total number of prey. A higher proportion of *Crocidura* in the diet of *T. alba* compared with *A. otus* was also noted in Poland (Kitowsky, 2013), and Greece (Alivizatos, 1999).

Our analysis suggests that *T. alba* and *A. otus* have a very similar winter diet on the Crimean Peninsula. In different areas of their range, both species overlap widely in diet. In Pennsylvania (USA), the dietary overlap coefficient was 0.99 (Khalafalla & Iudica, 2010), while in Eastern Poland 0.832 (Khalafalla & Iudica, 2010; Kitowsky, 2013) and Romania 0.87 (Petrovici et al., 2013). This demonstrates that, in sympatry, *T. alba* and *A. otus* tend to converge toward the same spectrum of prey. Variation in consumption of some prey species could be a result of difference in habitat use or prey-handling ability.

The number of prey species per owl pellet differed from the number of prey species per trap, both from the trapping at a regional (Evstafiev, 2016) and local scale. At a regional scale, *Sylvaemus witherbyi* (Thomas, 1902) was the most captured species accounting for 45.4% of all trapped mammals. However, it was only accounted for 1.6% and 3.1% of all prey individual in pellets of *T. alba* and *A. otus* pellets, respectively. *Mus musculus* reached 33.2% of all captured mammals, but it was absent in pellets of *T. alba* and accounted for less than 5% of all prey in pellets of *A. otus*. In contrast, *Microtus socialis*, the most consumed rodent species by owls, accounted for only 6.8% of all trapped mammals. The captures of shrews were rare in the trappings and their proportion was low in the pellets of *A. otus*. However, shrews accounted for almost a third of all consumed prey by *T. alba*.

At a local scale, we captured three small mammal species in traps, with *Mus musculus* being the most frequent species, followed by *Sylvaemus witherbyi* and *Crocidura suaveolens* (Table 1). The fact that the proportion of species in traps notoriously differed with the ratio in pellets suggests that both *T. alba* and *A. otus* preyed differentially upon small mammals during winter in the study area. However, the small number of pellets and low trapping effort were insufficient to conclude prey selection robustly. Differences in diet diversity between *T. alba* and *A. otus* species could be associated to differences in hunting range, prey-handling ability or capture efficiency. On other parts of their range, these species also differ in diet diversity. In Israel and USA, the diet diversity of *A. otus* was higher than that of *T. alba* (Leader et al., 2010). On the contrary, in East Poland, *T. alba* showed a more diverse diet than *A. otus* (Kitowsky, 2013).

Conclusions

On the Crimea Peninsula, the winter diet of *T. alba* and *A. otus* composed mainly of small mammals, but with some difference in the importance level of prey species. The high dietary overlap between both owl species suggest that they converge on the same prey species within their hunting range. Differential predation on small mammals by *T. alba* and *A. otus* suggest they could select their prey species. But this requires confirmation. The presence of the endangered *C. leucodon* in the diet of *T. alba* reinforces the utility of this owl species as a tool to detect threatened or rare small mammals that are not caught by traps and to increase information about their geographical distribution.

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ЗИМНЕЕ ПИТАНИЕ РЕДКОГО ВИДА *TYTO ALBA* В СРАВНЕНИИ С *ASIO OTUS* В КРЫМУ

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Ареал распространения *Tyto alba* перекрывается с ареалом *Asio otus* на значительной части Палеарктики. Оба вида приспособлены к охоте на открытой местности и выбирают схожую добычу. Данные о *T. alba* в Крыму и на прилегающей территории крайне скудны, в то время как *A. otus* является обычным видом. Целью нашего исследования было описание спектра добычи *T. alba* и сравнение степени перекрывания трофической ниши с *A. otus*. Мы оценили рационы на основе содержимого 48 погадок *T. alba* и 88 погадок *A. otus*, собранных с января по март 2018 года в западной части Крымского полуострова. Одновременно мы оценили доступность добычи мелких млекопитающих, установив 150 пружинных мышеловок в районе места сбора погадок. Останки млекопитающих содержали 99.2% погадок *T. alba* и 100% погадок *A. otus*. Наиболее потребляемой добычей обоих видов была *Microtus socialis* (52.3% и 74.4% всех жертв). Субдоминантом в погадках *T. alba* была *Crocidura leucodon* – редкий вид крымской фауны. Диета *T. alba* была более разнообразной, чем диета *A. otus* (индекс разнообразия Шеннона: 1.1 и 0.76, индекс Симпсона: 0.51 и 0.31, соответственно). Тем не менее, их диеты широко перекрываются (индекс Пианки = 0.94). Доля видов добычи в погадках не коррелировала с их соотношением в ловушках. Наличие находящихся под угрозой исчезновения *Crocidura leucodon* в рационе *T. alba* показывает большое значение этого вида в качестве инструмента обнаружения находящихся под угрозой или редких мелких млекопитающих, которые не попадают в мышеловки и для увеличения информации об их географическом распространении.

Ключевые слова: Aves, Strigiiformes, белобрюхая белозубка, общественная полевка, перекрывание трофической ниши, спектр питания