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DOES THE ABUNDANCE OF VOLES *Microtus* spp. STILL DETERMINE A NUMBER OF WINTERING LONG-EARED OWLS *Asio otus*?

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Abstract

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Long-eared owl *Asio otus* is a specialist predator, hunting primarily upon voles *Microtus* spp. Because size of the territory and breeding success of the predator depend on food availability, the number of long-eared owls wintering in a given locality is likely determined by the local abundance of voles. The amplitude and regularity of their cycle have been recently diminished and quantitative assessment of such a cycle is currently unavailable. Diet and number of wintering owls were monitored during two winters (2005/06 and 2006/07) in Busko-Zdrój and Pińczów (south-central Poland). It was found that number of voles is still a factor determining number of wintering owls, also every flock in particular locality has its' own dynamics of owl number. Research on predators' diet – especially specialists like long-eared owl – is nowadays very important because of vole fluctuation cycle disturbances caused mainly by global warming.

Key words: owl, wintering, diet specialisation, predator–prey relationship, small mammals, cycles' disturbance.

Introduction

Long-eared owl *Asio otus* is a bird species breeding in the whole area of Poland, although not numerous. From spring to autumn owl occupies individual territory established usually in the agriculture landscape. These owls breed in left nests of Corvidae or raptors located at the forest edge (Tomiałojć, Stawarczyk, 2003). Like most owl species, long-eared owl does not migrate at long distances, however individuals from the northern Europe can move during winter to the south, visiting also Poland. These movements are not regular and depend on food abundance in northern Europe (Mikkola, 1983). In winter, long-eared owls are not territorial; they gather in flocks of different sizes. These roosts often spend winter in the same place for many years (Mikkola, 1983). Long-eared owl is a food specialist, hunting primarily upon voles. Common vole *Microtus arvalis* constitutes the highest percentage of these birds diet in Europe (Sałata-Piłacińska, 1995; Pawłowska-Indyk et al., 1998; Zając, T., Zając, K., 1998). Also in Japan voles are its' main prey (Chiba et al., 2005). In the USA, however, this owl is more opportunistic: about 60% of its' diet were composed of two mice species *Peromyscus* spp. while four species of voles constituted only 8% of diet (Craig et al., 1985).

Food abundance and weather conditions are key factors influencing the reproductive success and distribution of animals (Newton, 1998; Cox, Moore, 2005; Begon et al., 2006). In many birds of prey, variations in vole abundance have been found to affect breeding success, e.g. American kestrel *Falco sparverius* (Wiebe, Bortolotti, 1992); Eurasian kestrel *Falco tinnunculus* (Korpimäki et al., 2000); ural owl *Strix uralensis* (Brommer et al., 2003); tengmalm's owl *Aegolius funereus* (Hipkiss, Hörnfeldt, 2004). Common vole, dominating in long-eared owl's diet, is a very numerous mammal in Europe, occupying similar environment as these birds. Its' population number changes every 3 years, which is called 'fluctuation cycles'. After the breeding season of a 'peak vole' year, the population number decreases during winter and it is being rebuilt during next 3 years to the next peak (Petty, Fawkes, 1998). Studies of many predators show that the diet-specialists (as long-eared owl) adapt their number to abundance of their prey (Jędrzejewski, Jędrzejewska, 2001). For birds of prey in Fennoscandia, small voles (especially field vole *Microtus agrestis* and bank vole *Myodes glareolus*) have been viewed as the primary prey during breeding. There has been a regular cycle in vole abundance, varying from a 3-year cycle in southern Fennoscandia to a 5-year cycle in the north and northeast (Sundell et al., 2004), although the amplitude and regularity of the Fennoscandian vole cycle has, in recent years, diminished (Henttonen, 2000; Hörnfeldt et al., 2005; Saurola, Hanski, 2004). Quantitative assessment of such a cycle is currently unavailable. For comparison, long-eared owls in western Switzerland exhibit a strong numerical response without a time lag to the abundances of a 7-year water vole cycle (Weber et al., 2002). In a previous study, *Microtus* vole dynamics were found to be also spatially better synchronized in an agricultural landscape exhibiting relatively mild winters than in a forested landscape with continental climatic conditions, including more snow (Huitu et al., 2003). It was suggested that the observed difference was primarily due to differences in landscape structure, although possible effects of varying climatic conditions could not be entirely ruled out (Huitu et al., 2003).

The main goal of this study was to check is the abundance of Microtidae still significant factor determining changes of the wintering owls' number in the area of central Europe. The first winter of this study was performed just after the breeding season with 'peak voles' (*M. arvalis*, *M. agrestis*) densities, whereas the second studied winter occurred while the vole population was rebuilding (personal observations). If voles' fluctuation cycles are being irregular, influence of voles' abundance on many aspects of owls' ecology is particularly worth noticing. During the second season I predicted existing one of scenarios:

- Owls flocks would be smaller. The number of voles in owl pellets should be lower than those collected in the first winter.
- Number of wintering long-eared owls could be higher during the second winter if a rebuilding population of voles was being exploited by a smaller number of owls.
- There would be also no differences between number of *Microtus* spp. from representative number of pellets collected both years because only the number of owls is being changed, suited to actual vole abundance.

Because of vole fluctuation cycles disturbance and other environmental factors influencing owls' wintering – like climate change, I could not simply predict which scenario would happen.

Material and methods

The study area was located in Ponidzie – the part of Niecka Nidziańska, between Kielecko-Sandomierska and Krakowsko-Częstochowska uplands, south-central Poland (Kondracki, 2000). Because of its' agricultural landscape and huge open areas, Niecka Nidziańska is a region where many long-eared owls usually spend winter (Chmielewski et al., 2005). Data were collected during two winters (2005/2006 and 2006/2007) at two sites: Busko-Zdrój and Pińczów (Fig. 1). In this way the results are not accidentally for one place or one season. In Busko-Zdrój, owls' flock appeared in November and disappeared in March (both years). Owls rested on trees next to park and health resorts, near the hospital and Krystyna Jamroz' house – places frequently visited by many people. Species of trees at this wintering site were: *Salix alba*, *Thuja occidentalis*, *Pinus sylvestris*, *Picea abies*. In Pińczów long-eared owls were observed at the same time just behind the blocks between a school and Żwirki and Wigury Street. Species of trees used by owls at this site were: *P. abies*, *Tilia cordata* and *Salix alba*. While the ambient temperature dropped below zero, owls were usually hidden in old spruces. This site was also often visited by people.

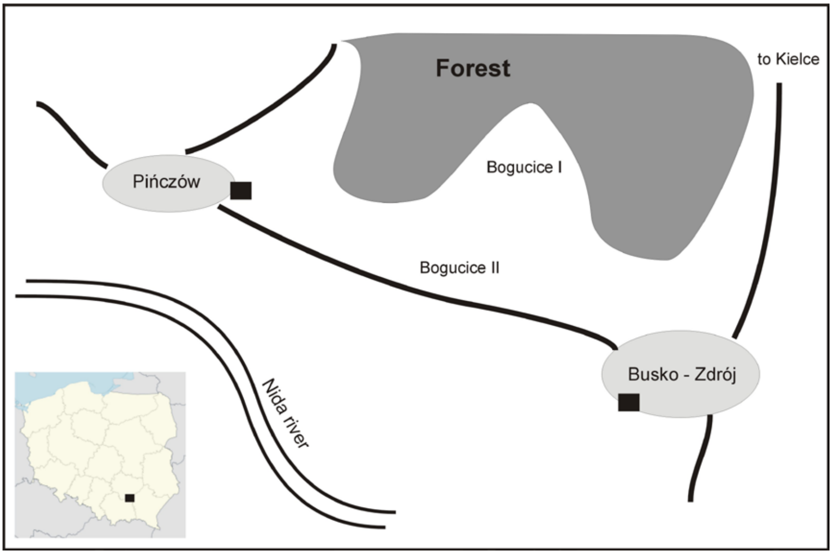

Fig. 1. Localisation of the study area in Poland and the two wintering sites of long-eared owls: Busko-Zdrój and Pińczów (marked by black squares; preparation of map: E. Grzędzicka).

Owl pellets were collected every 2 weeks, seven times per season, always the same days in Busko-Zdrój and Pińczów sites between 8 and 10 a.m. Long-eared owls' flocks spend winter on the same place, in the evening flying synchronously to hunt all night and then birds return to the same groups of trees about dawn. When they have difficulties in searching for victims, some owls do not return after night looking for better hunting site, so size of flock in the morning mirrors their fluctuations (Mikkola, 1983; personal observations). Size of owls' flocks (number of birds resting on trees in the morning) and the weather conditions (temperature and snow cover) were monitored at both wintering sites – always by one person. Temperature was measured with thermometer, while snow height – with surveying tape during controls in localities. Places chosen for measures were open areas without traces and other snow cover disruptions, representing average values of snow cover and temperature in locality.

Pellets contain fur, teeth and bones, which allow to identify the eaten prey (Pucek, 1984). Contents of collected pellets were analyzed in laboratory using 'dry technique', which means pulling out skulls with needle and other tools after pellets became dry (Mikusek, 2005). Altogether, 980 pellets were analyzed: 40 pellets from each of 14 collections (2 years) from Busko-Zdrój and 30 pellets from each of 14 collections from the second site.

Statistics. To check the differences between number of prey items, non-parametric Kruskal test was used, while variance of owls' number was described using One-way ANOVA and Bartlett's test for homogeneity of variance. Difference between number of owls was also checked with U Mann–Whitney test. GLZ model was calculated to detect influence of prey items, locality (continuous predictors) and season (qualitative predictor) on wintering – dependent factor was the number of owls. All analysis was done in programs: Statistica v.2 and KyPlot 2.3 beta.

Results

Pellets analysis showed a high share of voles in the diet of long-eared owls during winter, with domination of *Microtus arvalis* (70–83.2% during two seasons in Busko-Zdrój; 54.5–72.5% in Pińczów). In the first season, also the percentages of *M. agrestis* were really high, especially in Pińczów – 27.5% while in second locality during the same year – 21.1%. At both wintering sites owls' diet included similar prey species, but the one from Pińczów was more diverse (Bartlett's test = 6.78, $P = 0.009$, $df = 1$; Tables 1 and 2). Other victims hunted by owls were mice, especially *Apodemus agrarius* (4.5–6% during 2 years in Busko-Zdrój; 7–12% in Pińczów) and *A. sylvaticus* (2.1–2% in Busko-Zdrój and 7–12% in second locality). Common animals like *Sorex araneus*, *Micromys minutus*, rats, birds and insects were prepared in low numbers from pellets. It is worth noticing that *Dytiscus marginalis* was found in both localities during second winter: one from larger wintering place in Busko-Zdrój and four ones in the second locality.

During the first winter (2005/2006) about 40 owls were observed in Busko-Zdrój. The birds started to fly away at the end of February. In Pińczów during winter 2005/2006, usually

T a b l e 1. Diet composition (number of prey items and their percentages in analyzed pellets) of long-eared owls wintering in Busko-Zdrój during the two consecutive winters. $N = 280$ pellets per winter (560 pellets in total).

Prey taxa	**2005/ 2006**		**2006/ 2007**	
	Number	**%**	**Number**	**%**
Voles				
Microtus arvalis	536	70.0	666	83.2
Microtus agrestis	161	21.1	39	5.0
Microtus oeconomus	1	0.2	-	-
Myodes glareolus	2	0.3	-	-
Mice and rats				
Apodemus agrarius	34	4.5	48	6.0
Apodemus sylvaticus	16	2.1	15	2.0
Apodemus uralensis	–	–	3	0.4
Apodemus sp.	4	0.6	6	0.7
Micromys minutus	4	0.6	4	0.5
Rattus norvegicus	-	-	2	0.2
Other prey				
Sorex araneus	-	-	8	1.0
Aves	4	0.6	7	0.9
Dytiscus marginalis	-	-	1	0.1
Total	**766**	**100**	**799**	**100**

T a b l e 2. Diet composition (number of prey items and their percentages in analyzed pellets) of long-eared owls wintering in Pińczów during the two consecutive winters. N = 210 pellets per winter (420 pellets in total).

Prey taxa	**2005/ 2006**		**2006/ 2007**	
	Number	**%**	**Number**	**%**
Voles				
Microtus arvalis	340	54.5	347	72.5
Microtus agrestis	172	27.5	24	5.0
Myodes glareolus	1	0.2	–	–
Mice and rats				
Apodemus agrarius	43	7.0	57	12.0
Apodemus sylvaticus	50	8.0	24	5.0
Apodemus uralensis	2	0.4	1	0.2
Apodemus sp.	–	–	3	0.6
Micromys minutus	9	1.4	1	0.2
Rattus norvegicus	–	–	1	0.2
Rattus sp.	–	–	1	0.2
Other prey				
Sorex araneus	1	0.2	1	0.2
Aves	5	0.8	15	3.0
Dytiscus marginalis	–	–	4	0.9
Total	**625**	**100**	**479**	**100**

T a b l e 3. Number of long-eared owls observed at the two wintering sites on consecutive days of pellet collection during winters 2005/2006 and 2006/2007.

Control dates	**Busko-Zdrój**	**Pińczów**	**Control dates**	**Busko-Zdrój**	**Pińczów**
3 Dec. 2005	40	24	1 Dec. 2006	36	11
18 Dec. 2005	35	26	16 Dec. 2006	33	11
2 Jan. 2006	16	26	3 Jan. 2007	18	6
14 Jan. 2006	36	12	14 Jan. 2007	28	7
27 Jan. 2006	34	16	28 Jan. 2007	9	5
13 Feb. 2006	30	18	12 Feb. 2007	23	6
27 Feb. 2006	28	10	24 Feb. 2007	15	1
	Mean = 31.3	Mean = 18.8		Mean = 23.0	Mean = 6.7
	SD = 7.8	SD = 6.6		SD = 9.9	SD = 2.6

more than 20 owls (maximum 26) were observed. In contrast to the first season, the number of owls in both sites was lower and more fluctuating during the second winter: 2006/2007. General number of owls' was different between both wintering sites (Z = 3.33, P = 0.0009) and comparing two seasons (Z = –2.43, P = 0.015). Only in Pińczów owls' number variance between two seasons was statistically significant (F = 18.41, P = 0.001, df = 1), while in Busko-Zdrój variance was not important (F = 2.95, P = 0.11, df = 1). Number of owls during research from both localities is presented in the Table 3.

T a b l e 4. Number of rodent prey items belonging to the two main genera: *Microtus* and *Apodemus* found in consecutive owl pellet collections from the two wintering sites. Dates with deep snow cover are shown.

Date of pellets' collection	**Busko-Zdrój**		**Pińczów**	
	Microtus	***Apodemus***	***Microtus***	***Apodemus***
3 Dec. 2005	100	7	74	3
18 Dec. 2005	111	1	75	4
2 Jan. 2006	81	5	74	4
14 Jan. 2006 (snow)	94	21	46	27
27 Jan. 2006	110	5	51	12
13 Feb. 2006	106	4	62	18
27 Feb. 2006	96	11	57	12
	Mean = 99.7 SD = 10.6	Mean = 7.7 SD = 6.6	Mean = 62.7 SD = 11.9	Mean = 11.4 SD = 8.8
1 Dec. 2006	100	14	77	30
16 Dec. 2006	123	16	73	9
3 Jan. 2007 (snow)	122	10	49	15
14 Jan. 2007 (snow)	104	11	45	6
28 Jan. 2007	72	2	12	4
12 Feb. 2007	102	7	55	13
24 Feb. 2007	82	12	60	8
	Mean = 100.7 SD = 18.9	Mean = 10.3 SD = 4.6	Mean = 53.0 SD = 21.6	Mean = 12.0 SD = 8.7

It was found out that number of prey items from *Microtus* genera prepared from pellets were not different comparing all single collections between two seasons in Busko-Zdrój ($H = 0.06$, $P = 0.79$) and in Pińczów ($H = 0.92$, $P = 0.34$); there were also no differences between number of *Apodemus* prey items during two seasons in Busko-Zdrój ($H = 1.48$, $P = 0.22$) and in Pińczów ($H = 0.2$, $P = 0.65$) – presented in Table 4. Difference of owls' number between

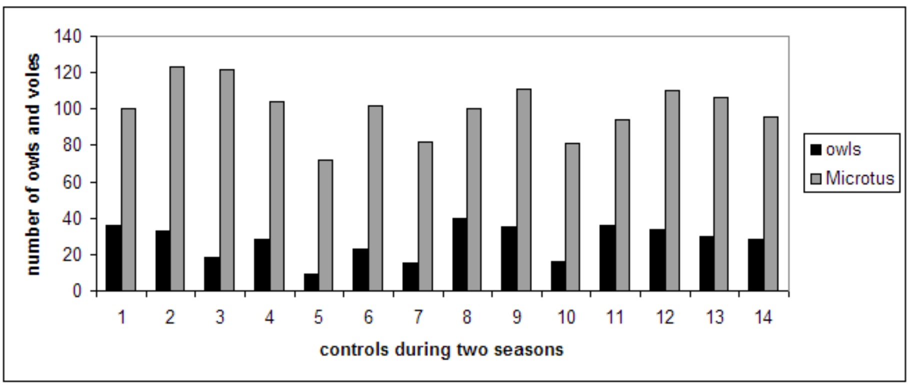

Fig. 2. Number of owls and voles during all visits in Busko-Zdrój (controls and pellets' collections 1–7 done during first winter; 8–14 during the second season).

two seasons encouraged to check if there was a relationship between them and number of prey items from *Microtus* genera (Figs 2, 3). GLZ model was used to check the influence of victims' number from two main genera and effect of season on the wintering roosts (Table 5). It was found out that number of voles and season were statistically significant for the number of owls. When results from two localities were summarized, *Microtus* was still the factor determining birds' number, there was also significant effect of locality.

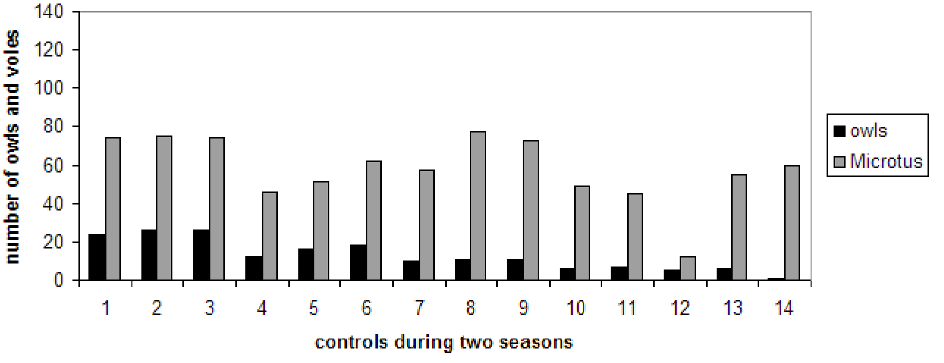

Fig. 3. Number of owls and voles during all visits in Pińczów (controls and pellets' collections 1–7 done during first winter; 8–14 during the second season).

T a b l e 5. GLZ model with influence of two main genera of prey items number and season on the owls' number wintering in Busko-Zdrój (I), Pińczów (II) and two localities summarized (I + II) – in the third case also effect of locality was checked.

Localities	**I**		**II**		**I + II**	
Predictors	**Wal.**	**P**	**Wal.**	**P**	**Wal.**	**P**
Microtus, N	**7.1**	**0.008**	**19.9**	**0.000**	**15.4**	**0.000**
Apodemus, N	**4.0**	**0.045**	0.0	0.947	1.6	0.201
season	**9.8**	**0.002**	**30.6**	**0.000**	0.0	0.901
locality					**19.5**	**0.000**
season*locality					3.4	0.064

Discussion

The use of prey remains collected from wintering sites to describe the diet of owls has quite a long history in ornithology. This method has also been used extensively to compare the relative abundance of different groups of animals in the diet. The high percentage of field voles *M. arvalis* found in this study in the diet of long-eared owl from Niecka Nidziańska is consistent with the results of other authors (Sałata-Piłacińska, 1995; Pawłowska-Indyk, 1998; Zając, T., Zając, K., 1998), while high percentage of *M. agrestis* during first winter was not found before.

The reason of this new effect could be a wet habitat of hunting areas, near Nida Valley. At both wintering sites owls' diet included similar prey species, but the one from Pińczów was more diverse (Tables 1, 2). It was found out that number of prey items from *Microtus* genera prepared from pellets were not different comparing all single collections between two seasons in Busko-Zdrój and in Pińczów, there were also no differences between number of *Apodemus* prey items (Table 4). In January the percentage of mice *Apodemus* spp. in the diet increased. Mice are active on the snow cover while voles move under it and are difficult to be hunted (Pucek, 1984; Reichholf, 1996). Both wintering sites were in towns and therefore more synanthropic small mammals (as rats, house mice) were expected in the diet of long-eared owls (Romanowski, 1988). Pellets analysis showed only four individuals of *Rattus* spp., all during the second winter when the number of field voles in pellets decreased. Moreover, common shrews or bank voles were also very rarely eaten by owls. So, the diet shows that although owls wintered in towns, they still were hunting in open areas outside towns (presumably on fields and meadows), this choice confirms their specialization in hunting habitat and prey type.

Interesting result of this study is the number of owls wintering at the same site was changing from year to year and even among consecutive controls within each year. Although in Busko-Zdrój there was no variance comparing number of owls during two seasons, flock has been changing in statistically significant way in Pińczów. This phenomenon can be caused by environmental factors, which is reflected by the differences in diet composition found from consecutive collections of pellets. The influence of environmental factors (like temperature and rain) on long-eared owls diet was investigated in Italy: cold days resulted in higher percentage of mice, whereas there was no influence of rain (Rubolini et al., 2003). At both Busko-Zdrój and Pińczów sites, the maximum number of wintering owls was lower during the second winter. How can it be explained? Long-eared owl, as a dietary specialist, shows rapid numerical responses to changes in densities of voles (Korpimäki, Norrdahl, 1989, 1991). This reaction has been observed when the number of wintering owls changes every year (Petty, Fawkes, 1998). In this study, 2005 was the year of maximum number of voles (personal observations). More owls wintered during winter 2005/2006 than during the next winter, when the vole population was low. Also the numerical responses of raptors, as well as changes in the composition of their diets, are usually synchronous with vole population densities (Hendrickson, Swan, 1938; Galushin, 1974; Sundell et al., 2004). Results imply that vole abundance is the most important factor for long-eared owl wintering decisions in observing populations – including common voles and water voles. Vole population vary cyclically in their numbers, e.g. Korpimäki et al. (2005) found evidence of 8–10 year water vole cycles in western Finland. Such a cycle may have occurred in our study area as well. Nevertheless, quantitative assessment of such a cycle is currently unavailable. Long-eared owls in western Switzerland exhibit a strong numerical response without a time lag to the abundances of a 7-year water vole cycle (Weber et al., 2002). We cannot establish a direct relationship between abundance of voles and long-eared owls wintering in this study population. Nevertheless, it seems intuitive that the differences across years in the number of owls reflect changes in the abundance of the voles themselves.

Comparison between two wintering sites: diet composition and flocks' sizes every control showed local differences. Lower percentage of *Microtus* spp. in Pińczów every year and lower number of owls mean that this site is not so attractive for wintering as Busko-Zdrój. There were no differences between seasonal abundance of *Microtus* spp. and *Apodemus* spp. among single winter locality in both towns. The condition at site and diversity or abundance of local prey-mammals (in this case: voles) determine the flock size and changes in owls number. Availability of voles is a factor determining number of owls wintering at one locality and its changes between seasons. Compared to the other studied owl species, long-eared owl is more of a vole specialist (Korpimäki, 1981; Mikkola, 1983; Kullberg, 1995). This may be the reason why wintering long-eared owls showed a positive relationship with voles' number even if their fluctuation cycles are distinguished.

In a previous study, *Microtus* vole dynamics were found to be spatially better synchronized in an agricultural landscape exhibiting relatively mild winters than in a forested landscape with more continental climatic conditions, including more snow (Huitu et al., 2003). It was suggested that the observed difference was primarily due to diversity in landscape structure, although possible effects of varying climatic conditions could not be entirely ruled out (Huitu et al., 2003). Even subtle differences in climatic conditions between adjacent areas may produce distinct differences in the spatial dynamics of animal populations (Rueness et al., 2003; Stenseth et al., 2004; Klemola et al., 2006). For example, Stenseth et al. (2004) demonstrated that the spatial dynamics of lynx *Lynx canadensis* differ on the two sides of a non-geographic barrier in response to differences in the physical properties of snow cover. Similarly, varying levels of snow thickness may have differing effects on the dynamics of vole populations, for example through the effectiveness of their generalist predators (Hansson, Henttonen, 1985; Hanski et al., 1991). In areas with relatively little snow, sporadic warm spells during winter may also result in ice formation on the ground, which restricts access to food resources and reduces vole survival (Aars, Ims, 2002; Korslund, Steen, 2006), while in areas with a more stable snow cover these effects may not occur. Such effects may have contributed to the inter-areal differences observed in vole population synchrony as reported in Huitu et al. (2003). In that a greater degree of landscape fragmentation was not associated with a lower degree of spatial synchrony in the dynamics of *Microtus* voles, despite differences in landscape structure and in predator abundance between the landscapes. This suggests that the source of spatial synchronization of vole dynamics lies primarily in a synchronous stochastic environment, most likely related to weather conditions. Thinner snow cover and earlier snow melt may increase predation on voles (Hansson, Henttonen, 1985; Korpimäki, 1986; Halonen et al., 2007); alternating thaw and freezing cycles (frost seesaw) can be harmful for wintering voles (Aars, Ims, 2002; Solonen, 2006). Reduction of the snow layer could lead to a paradoxical pattern where hunting conditions and even winter survival are improved due to thinner snow cover (Korpimäki, 1986; Francis, Saurola, 2004).

Conclusion

Results are consisted with my third prediction: I found no differences between number of *Microtus* spp. from the same number of pellets collected from particular locality in both years because changeable was only the number of owls, suited to actual vole abundance. Voles' availability is still a factor determining the number of wintering owls, also every birds' flock in particular locality has its' own dynamics of owls' number. Research of long-eared owls' diet is nowadays very important because of global warming affecting disturbances in their main victims' fluctuations cycle. We should control this situation because it influences owls' number, distribution, survival and conservation status.

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