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Feeding conditions in breeding areas and selection of lekking sites by Great Snipe (*Gallinago media*) in Moscow Region, Russia

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Great Snipe (*Gallinago media)* was included in the Red Data Book of the Moscow Region (central European Russia) after this species numbers had decreased dramatically in the 20th century. Certain range expansion and, particularly, growth of number of leks has been observed in Great Snipe in the north of this area during the last two decades. Food resources can belong to important drivers of change in Great Snipe distribution in breeding areas and, accordingly, need to be accounted for when developing conservation measures. Therefore, we studied influence of feeding conditions on selection of sites for lek formation by the Great Snipe in 2017 at the breeding sites in the north of the Moscow Region (56°40′ N, 37°40′ E). We found that neither parameters related to amount (abundance and biomass of earthworms, soil pH) or availability (abundance of earthworms and soil penetrability) of feeding resources had pronounced impact on selection of lekking sites by birds in our study area. The abundance and biomass of earthworms, main prey of Great Snipe, contributed the most to difference in discriminant analysis between leks and random sites at agricultural lands, but this difference was still not significant. Two leks of Great Snipe were located on acidic mesotrophic bogs where earthworms were absent. Apparently, food resources do not currently represent a limiting factor for Great Snipe in the north of Moscow Region. However, constant monitoring of habitats, including food supply, is needed in the species' breeding areas.

1. Introduction

Great Snipe (*Gallinago media*) is a polygamous species that forms leks, where males perform displays at night and mate with females (Kålås 2004). Its main breeding range is located in Russia, and the European population declined by 5–15% over the three generations and was assessed as near threatened on the global scale (BirdLife International 2019). Breeding population in the Moscow Region, central European Russia, is included in the regional Red Data Book

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(2018), however, certain range expansion and, particularly, growth in the number of leks, were observed in the north of this area in the beginning of XXI century (Sviridova *et al.* 2016a).

Food supply and availability belong to the most important factors potentially limiting spatial distribution and reproductive performance in birds, and eventually resulting in population decline. Great Snipe is a food specialist with earthworms constituting ~90% of food biomass consumed by the species in its breeding areas (Løfaldli *et al.* 1992). In the Vologda Region of Russia 7 Great Snipes were kept in captivity for 10 days, during which period an average of 255 medium-sized earthworms were consumed by an adult bird per day (Nikiforov & Gibet 1987). The researchers concluded, that earthworm abundance substantially influenced numbers and spatial distribution of birds in floodplain meadows during post-nesting period, but published quantitative data were too scarce in this article to support this conclusion. In the isolated population of mountain subalpine region of Scandinavia Great Snipes form leks at sites characterized by higher abundance and biomass of earthworms compared to sites where leks are absent (Kålås *et al.* 1997). On lowland meadows in Poland, on the western periphery of main breeding range of the species, feeding sites of most Great Snipes are located close to leks, and earthworms constitute approximately 75% of soil invertebrate biomass (Korniluk & Piec 2016).

High energy expenditure during display activity on leks is typical for males of this species (Höglund *et al.* 1992). Females spend over 90% of their time incubating, raise broods without males and feed chicks during the first days after hatching (Løfaldli *et al.* 1992, Kålås 2004). Most females are known to lay clutches of eggs and move with broods in close vicinity to leks (Nikiforov *et al.* 1983, Korniluk & Piec 2016). Feeding behavior is not the predominant type of Great Snipe activity on leks, but a notable number of birds do feed there or in close vicinities (Kuz'min & Nikiforov 1983, Korniluk & Piec 2016). In our study area many visual observations of birds, records of bill marks and excrements indicated regular feeding of Great Snipes on grassland leks. Although some birds can feed at a high distance from leks (Korniluk & Piec 2016), feeding conditions at lekking sites are expected to be particularly important for Great Snipe. Therefore, assessment of feeding conditions at breeding sites of Great Snipe and their influence on selection of lekking sites by birds is of scientific and conservation interest.

2. Material and methods

Data were collected in 2017 at the IBA "Homeland of the Crane" (north of Moscow Region, 56°40′ N, 37°40′ E). The study area is located at the border of the Dubna river lowland and the Taldom upland, and covered mostly by wet birch and black alder forests as well as some transitional bogs alternated with agricultural lands. Agriculture had been relatively intensive there in the 1970s–1980s, but then up to 60–70% of hays, pastures and arable lands were abandoned during recession of 1990s–2010s. In particular, grazing was totally absent for at least five years on land with Great Snipe leks under study. The waterlogging has been increasing during recent years on farmland in the area due to land abandonment and climate change (Sviridova *et al.* 2016a, b).

The main period of Great Snipe activity in the study area occurs in May and the first half of June, when from 7 to 33 birds gather on leks (Sviridova *et al.* 2018b). Food resources were studied only on permanent leks, existing at the same site for five years or more (Sviridova *et al.* 2016a). Distribution of Great Snipe leks in floodplains depends on the pattern of spring flood (Kuz'min & Nikiforov 1983). In 2017 some leks in floodplain dried off by April 25–28, during the period of Great Snipe arrival, but were flooded again in the first pentad of May, due to two-peak pattern of flood on the Dubna river. After water-level decline, birds formed leks at their usual sites as in seasons without flooding (Sviridova *et al.* 2018b). According to data from the nearest weather station "Pereslavl-Zalessky", the amount of precipitation in 2017 was higher than average in April and May, *i.e.* 95.9 mm and 58 mm, and 33 mm in June (Bulygina *et al.* 2017). Prolonged flooding and heavy rainfall in Spring resulted in high soil moisture during the main period of Great Snipe activity in 2017. This created favourable conditions for earthworms, which have maximum reproduction rate and body mass at soil moisture of 60–85%, and refrain from migration deeper into the soil until its wetness drops below critical for worms threshold, 20–35% (Chekanovskaya 1960).

Biomass of earthworms is more important for Great Snipe than species diversity of earthworms (Løfaldli *et al.* 1992), so we did not study the latter. Abundance and biomass of worms are affected by soil pH values (Chekanovskaya 1960, Kålås *et al.* 1997), while soil penetrability is important for probing snipes (Kålås 2004), so we analysed both these soil properties.

Soil samples of 15 × 15 cm area were taken on leks to the depth of 10 cm, to exceed bill length of Great Snipes, which according to our measurements was maximum of 66 mm long in males (n = 127) and 71 mm in females (n = 19). The samples were processed on the following day, which included counting of earthworms and determining their total wet mass. Abundance and biomass were considered as separate factors. Then we estimated number of individuals per 1 m^2 (ind/m^2) and mass of worms per 1 m^2 (g/m^2). Type of agricultural landuse was recorded during sample collection, because it is related to abundance of earthworms (Geraskina 2009).

Soil pH was determined in samples taken with a metal cylinder 5 cm in diameter and 5 cm high, and air-dried at the temperature +25°C. Sample portion of 1 g for peat soils and 10 g for other soil types was then mixed with 25 ml of cooled, boiled, distilled water and after 25 minutes pH of this suspension was measured (Timeiko 2016). We used soil acidity classification by Kormilitsina *et al.* (2006), and did not measure pH on sedge-sphagnum bogs, because this habitat is well known for highly acidic reaction. Soil penetrability was determined dropping a metal stick (235 g) vertically from the height of 1.1 m at three points within a lek, and then measuring depth of hole made by the stick in the ground. Soil penetrability was calculated as a mean of three measurements.

Not all, but most of Great Snipes stay and feed in a lek vicinity of maximum 0.5 km both at night and during daytime (Kuz'min & Nikiforov 1983, Korniluk & Piec 2016, our observations), and they need moist soil to probe. Therefore, we collected samples on wet feeding sites near known leks which were selected as the closest to lek grass-sedge swamp or overmoist patch of grassland. Feeding site samples for leks on sedge-sphagnum transitional bogs were collected in more swampy patches.

Comparison of feeding conditions between known leks and sites without them required selection of random sites to assess abundance and biomass of earthworms, soil pH and penetrability. The Great Snipe is a highly specialised species with unevenly distributed leks (Kålås 2004, Sviridova *et al.* 2016a), so straightforward estimation of random points' positions would make no biological sense. Random sites (potential leks) were selected among localities meeting obligatory criteria for Great Snipe leks, but certainly unused for lekking during the last 20 years (Sviridova *et al.* 2016a). All of the following criteria were met at random sites: 1) either a complete absence of shrubs on grasslands, or the presence of single shrubs or trees; 2) elevated position of potential lek relative to surroundings; 3) heterogeneity of grass cover on potential lek and presence of patches with low vegetation (≤ 10 cm) or no vegetation; 4) presence of potential feeding site nearby, *e.g.* grass-sedge swamp or temporary puddle on poorly drained meadow.

In total, 62 soil samples were collected. They were taken from nine grassland leks and feeding sites near them (four were situated in the floodplain and five on the watershed, one of the latter was ploughed in 2017), and from two leks and two adjacent, more flooded, feeding sites on transitional bog. Eight random sites were selected both on the watershed and floodplain grassland, in each of which samples were taken at potential lek and potential feeding site nearby. Samples from eight random sites in sedge-sphagnum bog were not divided into potential leks and potential feeding sites, because more homogeneous structure of this habitat did not allow to make such division in a sensible way.

Spearman's rank correlation coefficient (r_s) and non-parametric Mann–Whitney *U*-test were used for pairwise comparison of variables and data subsets. Discriminant analysis was carried out to reveal factors contributing to differences between known leks and connected feeding sites and random sites. Statistical analysis was carried out in Statistica 10 (Statistica Soft inc. 2011) and PAST 3 (Hammer *et al.* 2001). Differences were considered significant at $p < 0.05$.

3. Results

3.1. Soil penetrability at lekking and feeding sites

Soil penetrability was studied only on agricultural lands. It did not differ between known and potential leks (n = 25, $z = 0.71$, $p = 0.48$). Differences were found between leks (known and potential combined) and feeding sites (known and potential combined) for entire data set (n = 50, $z = 3.54$, $p < 0.001$) and at the watershed (n = 26, $z = 3.33$, $p < 0.001$), but not in the floodplain (n = 24, $z = 1.67$, $p = 0.09$). Higher penetrability at feeding sites in the watershed is anticipated, because feeding sites are located in wetter areas than leks. Moisture and relief across the floodplain are more uniform, so the difference is not pronounced. Differences between floodplain and watershed were not found in any dataset.

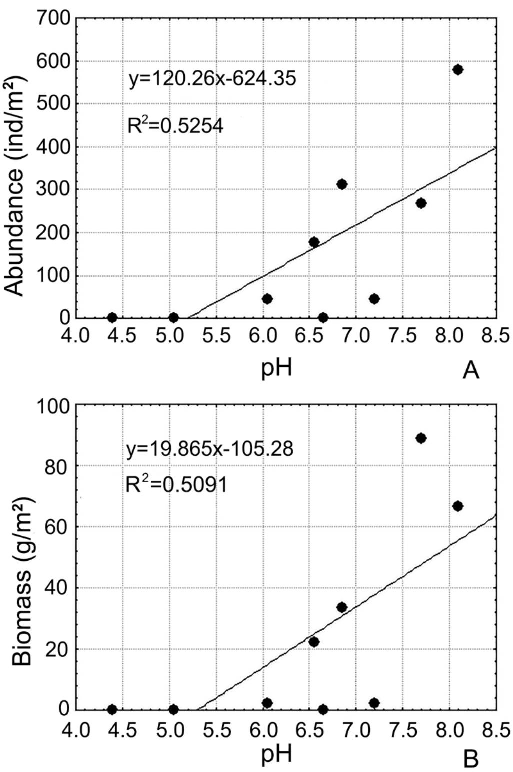

Fig. 1. Abundance (A) and biomass (B) of earthworms on leks in relation to soil pH.

3.2. Forage resources on watershed and floodplain grasslands

Soil pH varied from 5.9 to 7.8 in the watershed and from 4.4 to 8.75 in the floodplain. It did not differ between known and potential leks (n = 25, $z = 0.65$, $p = 0.51$) and between known and potential feeding sites (n = 25, $z = -0.31$, $p = 0.76$). Difference in pH between the floodplain and watershed was found for the entire data set only (n = 50, $z = -2.6$, $p < 0.01$), however, median pH values in the floodplain (6.25) and in the watershed (6.6) were both within optimum range for reproduction of most earthworm species (Chekanovskaya 1960). Worms were absent in 3 of 6 samples with soil pH values ≤ 5, unfavorable for reproduction of most earthworm species. In the rest three samples biomass was even higher (13.3, 44.4 and 57.8 g/m^2) than in some samples with neutral pH (*e.g.*, 2.2, 11.1 and 33.3 g/m^2), and we cannot say if this was due to contribution by species with preference to acidic soils. Soil pH correlated with earthworm abundance and biomass on known leks only ($r_s = 0.76$ and $r_s = 0.78$, respectively; n = 9, $p < 0.05$). It also varied widely there, and two of three zero abundance/biomass values were observed at sites with critical for earthworm development soil pH (Fig. 1).

The earthworm abundance and biomass correlated always positively (Table 1), *i.e.* the probability of successful searching for food related to higher abundance of potential prey is combined with the possibility for birds to get higher food biomass. The difference in the earthworm

Table 1. Correlation of earthworm abundance and biomass on agricultural lands ($p < 0.001$). L – known leks, PL – potential leks, FS – feeding sites near known leks, PFS – potential feeding sites.

Sample	n	r_s
L & PL combined	25	0.94
L	9	0.95
PL	16	0.95
FS & PFS combined	25	0.95
FS	9	0.98
PFS	16	0.90

Table 2. Pairwise comparison of abundance and biomass of earthworms between different types of sites and data subsets (Mann–Whitney *U*-test). * See legend for site types in Table 1 header.

Sample*	Abundance	Biomass			
	n	*z*-value	*p*	*z*-value	*p*
A. Differences between L and PL	25	–1.42	0.15	–1.98	< 0.05
B. Differences between FS and PFS	25	–0.57	0.57	–0.78	0.44
C. Differences between floodplain and watershed					
Entire dataset	50	–2.7	< 0.05	–2.4	< 0.05
PL & PFS combined	32	–2.69	< 0.05	–2.29	< 0.05
L & PL combined	25	–2.18	< 0.05	–1.96	< 0.05
PL	16	–2.09	< 0.05	–1.68	0.09
D. Differences between unmown and mown grasslands					
L	8	0.86	0.4	0.86	0.39
L & PL combined	24	–1.7	0.08	–2.46	< 0.01
FS	8	1.1	0.25	1.15	0.25
FS & PFS combined	24	0.03	0.97	–0.81	0.42

abundance between known and potential leks was insignificant, while biomass (Table 2A) was significantly lower on known than on potential leks (Table 2A, Table 3). Earthworm abundance and biomass did not differ between known and potential feeding sites (Table 2B, Table 3). Both parameters differed between floodplain and watershed (higher on the latter); on potential leks the difference was significant only for abundance (Table 2C, Table 3).

Among grassland leks, not ploughed in 2017, six were not mown for at least 15 years, and two leks were mowed in late summer 2016. On these leks and potential leks combined earthworm biomass was significantly higher on mown than on unmown grasslands (Table 2D, Table 3). Differences in biomass or abundance of earthworms were not found between other data subsets in these habitats (Table 2D).

Since analysed parameters did not differ between known and potential leks of Great Snipe, we conducted discriminant analysis using all four environmental variables: earthworm abundance and biomass, soil pH and penetrability. The largest contribution to separation of known and potential leks along discriminant axis is made by the abundance and biomass of worms (Fig. 2B), but the difference between these two lek groups was still not significant ($\lambda = 0.84$, $F(4.20) = 0.94388$, $p < 0.4592$). However, known leks (n = 9) are less variable along discriminant axis than potential leks (n = 16), of which seven fall in the range typical for known leks (Fig. 2A).

3.3. Food resources on bogs

Earthworms were not recorded in samples taken on transitional bogs. Other invertebrates representing potential prey for Great Snipe (Løfaldli *et al.* 1992, Kålås 2004) were found in these 12 samples and included in total 8 spiders and 13 eggs of Araneae, 8 larvae of crane flies *Tipula sp.,* 3 beetles Coleoptera, 3 ants *Formica uralensis*, 2 puparium of flies Brachycera and 1 green lacewing *Chrysopa sp.*

4. Discussion

Previously we showed that numbers of Great Snipe on leks in the Moscow Region did not

Table 3. Average biomass and abundance of earthworms on agricultural lands. * See legend for site types in Table 1 header.

Sample*	n	Abundance, ind/m^2	Biomass, g/m^2
L	9	157.9 ± 69.8	23.9 ± 11.7
PL	16	386 ± 105	153.6 ± 49.5
FS	9	232 ± 157.6	28.1 ± 17.9
PFS	16	230.5 ± 92.6	46.4 ± 22.5
L, PL, FS &PFS combined, in the floodplain	24	142.6 ± 49.3	46.3 ± 24.9
L, PL, FS &PFS combined, on the watershed	26	382.9 ± 86.5	98.4 ± 27.9
L & PL combined, in the floodplain	12	196.3 ± 92.4	77 ± 49.8
L & PL combined, on the watershed	13	403.7 ± 111.7	134.5 ± 48.3
L & PL combined, on unmown grasslands	14	190.4 ± 62.7	29.7 ± 10.5
L & PL combined, on mown grasslands	10	466.6 ± 156.5	216.9 ± 73.2

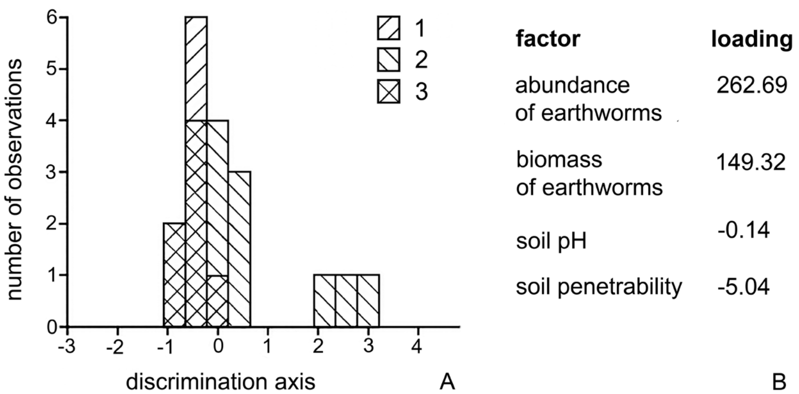

Fig. 2. Separation of leks and random points (potential leks) along the first axis (A) and contribution of variables to this separation (B). 1 – known leks, 2 – potential leks, 3 – overlap between known and potential leks.

depend on either landscape location of leks or soil penetrability (Sviridova *et al.* 2018b). In the current study we found that the penetrability of topsoil differed neither between known and potential leks/feeding sites nor between floodplain and watershed. Accordingly, this factor was unlikely to limit food availability for Great Snipe in our study area. These results differ from findings in Baltic countries and Scandinavia, where soil penetrability and wetness affected the presence of Great Snipes in breeding areas, and penetrability positively correlated with moisture and earthworm biomass (Løfaldli *et al.* 1992, Kuresoo *et al.* 2001). These differences can, probably, be explained by more even spatial distribution of wetness and soil penetrability across our study area at the current time due to expansion of waterlogging processes in the north of Moscow Region during recent years and associated stability of habitats wetness (Sviridova *et al.* 2016a, b).

Unambiguous influence of pH level on the earthworm abundance and biomass was not found in our study area. Again, this differs from the situation in Scandinavia, where ~80% of Great Snipe leks were situated in areas with pH ranging from 5.5 to 6.3 with corresponding higher biomass of worms (Kålås *et al.* 1997). In Scandinavia pH varied from 3.8 to 6.3

in subalpine habitats, where *Allolobophora caliginosa* constituted 70% of worms in the samples (Kålås *et al.* 1997). The latter worm species reproduces better at neutral or slightly alkaline pH (Chekanovskaya 1960), while pH ≤ 6 are often assigned to acidic soils (Kormilitsina *et al.* 2006). This may explain stronger relation of earthworm abundance/biomass to pH level in Scandinavian mountains. Soil pH range found on the farmlands in our study area is wider and favors reproduction of most earthworm species (Chekanovskaya 1960), which may result in more even distribution of them across this area.

In our study area, Great Snipes regularly feed on known grassland leks, and only earthworm abundance and biomass were positively correlated with pH level. However, a pronounced impact of worm abundance and biomass on selection of lekking sites by birds was not found. In Scandinavian mountains average worm biomass was lower at sites otherwise suitable, but unused by snipes for lekking compared with known lek areas (Kålås *et al.* 1997). In our study area average biomass of earthworms was, in contrast, significantly lower at known than at potential leks. Depletion of worm resources on leks due to predation by snipes can explain the latter finding, and under this scenario earthworm biomass could have been higher on leks before the start of breeding season. In Poland average earthworm biomass at feeding sites of Great Snipes during breeding season was higher than at random points in 2014, but lower in 2013 (Korniluk & Piec 2016).

It is noteworthy that earthworm abundance and biomass were significantly higher at watersheds than in floodplains in our study area, while 40% of Great Snipes used leks in floodplains (from 33 to 49% in different years) and fewer birds (from 23 to 35%, 31% on average) gathered on leks at watersheds (Sviridova *et al.* 2018a). In central Russia earthworm biomass and abundance are significantly reduced on lands that have been abandoned for over 14 years (Geraskina 2009). This can explain lower earthworm biomass at old unmown grasslands compared with younger mown meadows in our study area, however, about 50% of leks have been formed there at unmown abandoned lands (Sviridova *et al.* 2018b). Accordingly, food supply on lek and in its close vicinity does not appear to be a decisive factor for Great Snipes for selection of lekking sites at agricultural lands. This is also true for leks used by approximately 30% of Great Snipe on acid transitional bogs, lacking substantial food resources (Sviridova *et al.* 2018a). In Scandinavian mountains Great Snipe did not establish leks in areas with acid soils (Kålås *et al.* 1997). Bogs are adjacent to agricultural lands in our study area, and we rarely observed birds on bogs during day-time. Most likely, Great Snipes from bogs use surrounding grasslands for feeding.

Thus, contrary to our expectations, none of the analysed parameters related to amount (abundance and biomass of earthworms, soil pH) or availability (abundance of earthworms and soil penetrability) of forage resources currently have a pronounced impact on choice of lekking sites by snipes in the north of the Moscow Region. This difference from other breeding areas of Great Snipes is most likely caused by local features of snipe habitats in our study area, namely by higher evenness of soil moisture, penetrability and pH on agricultural lands. The latter can lead to more even distribution of earthworms on agricultural lands in our study area and, accordingly, provide more opportunities for Great Snipes to replenish their high energy expenditures, both on leks and in their vicinities. Additionally, discriminant analysis revealed partial overlap between scores of random points and known leks on agricultural lands, which can indicate suitability of some random sites for lek formation. Probably, habitats suitable for Great Snipe are prevalent at the current time in the north of the Moscow Region, an assumption which concurs with an increase of Great Snipe there during recent years (Sviridova *et al.* 2016a).

Our data demonstrate that currently food resources are not a limiting factor for Great Snipe in the north of the Moscow region, while heterogeneity of projective grass cover is important for birds choosing sites for lek formation there (Sviridova *et al.* 2018b). It was found in some studies that vegetation structure had more pronounced impact than earthworm biomass on selection of feeding sites by Great Snipes in breeding areas, particularly in certain habitat types preferred by this species (Løfaldli *et al.* 1992, Korniluk & Piec 2016). Available data imply that agricultural activities in areas inhabited by Great Snipes need not only stimulate an increase in earthworm numbers, but to be concentrated on wet areas with low sparse vegetation. However, the rollback to the intensive use of farmlands, which has started in the most recent years in our study area, can adversely impact both feeding conditions and vegetation structure in the current habitats used by Great Snipes. Conservation measures, aiming at the long-term preservation of the Great Snipe, need to include constant monitoring of habitat conditions in known breeding areas and appropriate management to prevent adverse changes in these conditions.

Heinäkurpan soidinpaikkojen valinta ja ravintotilanne Moskovan alueella

Heinäkurpan populaatiokoko on vähentynyt merkittävästi 1900-luvulla itäisessä Euroopassa Moskovan alueella. Viimeisten 20 vuoden aikana on kuitenkin havaittu lajin levittäytymistä pohjoiseen ja soidinten määrän kasvua. Ravintoresurssit voivat selittää pesimäalueen muutoksia, ja nämä on otettava huomioon suojelutoimia kehitettäessä. Tutkimme ravintoresurssien vaikutusta soidinpaikkojen valintaan Moskovan pohjoispuolella sijaitsevalla tutkimusalueella. Ravinnon määrään tai saatavuuteen (heinäkurpan päääsaaliin, lierojen biomassa ja runsaus, saavuttavuus tai pH) liittyvät muuttujat eivät olleet yhteydessä soidinalueen valintaan. Lierojen runsaus tai biomassa erosi eniten soidinten ja satunnaisesti valittujen maatalousympäristöjen välillä, mutta ero ei ollut tilastollisesti merkitsevä. Kaksi heinäkurpan soidinta sijaitsi mesotrofisilla soilla, joilla ei ollut lainkaan lieroja. Tuloksemme osoittavat, että ravintotilanne ei tällä hetkellä rajoita heinäkurpan esiintymistä. Jatkuvaa elinympäristöjen ja ravinnonsaatavuuden seurantaa kuitenkin tarvitaan

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