The effect of grassland management intensity on earthworms and leatherjackets

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Abstract

Grasslands play an important role in the provisioning of ecosystem services like biodiversity. Species-rich grasslands are important for aboveground biodiversity; however, it is unclear whether this also results in increased belowground biodiversity. The objective of our study was to assess earthworm (*Lumbricidae*) and leatherjacket (*Tipulidae*) populations in permanent grasslands with a gradient of grassland management intensity. In an on-farm research we compared intensively managed permanent grasslands (INT, n=12) with three types of extensively managed grasslands (EXT, n=3×12=36) varying in the degree of herb-richness, on sea clay soils in the Province of Friesland, The Netherlands. The intensively managed permanent grasslands had high fertilizer inputs (361 kg N ha^{-1} year^{-1}) and a high mowing frequency (4–5 cuts year^{-1}). The extensively managed grasslands received only solid farm-yard manure and the mowing date was postponed until the 15th of June (1–2 cuts year^{-1}). In March 2022, soil samples were taken in each field for soil chemical analysis, and to detect earthworms and leatherjackets. The number of adult and anecic earthworm numbers as well as the biomass of earthworms were significantly higher in the case of INT, and were positively correlated with N-fertilization and pH. There were no significant differences in the number of earthworms between the three types of EXT sward. The results of the abundance of leatherjackets showed a similar (non-significant) tendency as for earthworms, however the variation between fields was large. Our results show that there is a positive relationship between management intensity and earthworm abundance and biomass.

Keywords: grasslands, management intensity, biodiversity, soil, earthworms, leatherjackets

Introduction

Biodiversity of agricultural grassland systems is rapidly declining. This decline is due to a combination of several factors, including intensified grassland management associated with high fertilizer inputs and mowing frequencies (Vickery *et al*., 2001). Extensive grassland management improves plant species richness and related aboveground biodiversity. However, the effects of management intensity on belowground soil biota are relatively unknown and the results of previous studies are sometimes contradictory. Earthworms and leatherjackets are an important food source for several grassland birds. The objective of our study was to assess earthworm and leatherjackets populations in grasslands with a gradient of grassland management intensity.

Materials and methods

In March 2022 an on-farm research was established on sea clay soil in Friesland (The Netherlands) to compare four grassland management types in twelve replicates, 48 fields in total:

1. Intensively managed permanent grasslands dominated by perennial ryegrass (*Lolium perenne*) (INT);
2. Three types of extensively managed grasslands varying in the degree of species-richness. All extensively managed fields received limited amounts of farmyard manure (max. 20 tons ha^{-1} year^{-1}), and had their mowing date postponed after the 15th of June (Table 1).
   a. EXT1 were owned by farmers and had a low botanical species diversity;
   b. EXT2 were owned by farmers and had a high botanical species diversity;
   c. EXT3 were owned by Nature-organizations and had a high botanical species diversity.

A composite soil sample (30 cores, 0–10 cm depth, 2 cm diameter) was taken in each field and analysed for soil chemical properties (pH_{KCl}, Eurofins-agro, Wageningen, The Newtherlands). The abundance, biomass, species and functional groups of earthworms and leatherjackets were determined in two sods of 20x20x20 cm in each field. Soil moisture was measured at 15 locations in each field using a handheld soil moisture meter. Penetration resistance was measured using a penetrologger (0-10 cm depth, 30 locations in each field), which was used as an indicator of the difficulty for a meadow bird's bill in probing the soil. Plant species richness was determined in May in a plot of 25 m^2, and botanical composition was determined in two plots of 1 m^2 using Braun-Blanquet method. Linear Mixed Models (LMMs, using R package nlme) were used to assess the impacts of the four types of grassland. Some variables underwent a square root transformation for normality of residuals. A Poisson GLMM method (using glmmtmb package) examined the impact on total number of anecic earthworms and leatherjackets, while a negative binomial GLMM method assessed the impact on total number of epigeic and endogeic earthworms.

Results and discussion

Plant species richness ranged from 8 species per $25m^{-2}$ for INT to 22.6 species per $25m^{-2}$ for EXT3 in line with our set-up (Table 1). N-fertilization levels ranged from 10 kg N ha^{-1} $year^{-1}$ for EXT3 to 361 kg N ha^{-1} $year^{-1}$ for INT. EXT fields had a lower pH-KCl and penetration resistance, and a higher soil moisture content compared to INT fields. EXT3 also had a significantly lower soil P-Al and K contents compared to INT and EXT1.

The number of adult earthworms and the total biomass were significantly higher in INT compared to EXT3 (Table 1). The number of adult earthworms and earthworm biomass were positively correlated with N-fertilization (r=0.35; P= 0.015) and pH (r=0.39 ; P=0.07). This is in line with other studies (e.g. Edwards and Bohlen, 1996). The intensive management also had a positive effect on anecic earthworms. There was a positive correlation between the occurrence of anecic earthworms and N-fertilization (r=0.424; P=0.004). The results of the abundance of leatherjackets showed a similar (non-significant) tendency for earthworms (INT>EXT1/EXT2>EXT3); however, the variation between fields was large.

Table 1. Management, botanical, soil chemical and soil biological properties of the four grassland types (mean and standard deviation, n=12).

Selected properties	INT	EXT1	EXT2	EXT3	*P* value
N-fertilization (kg N ha^{-1} $year^{-1}$)	361 (82)a	104 (35)b	83 (42)b	10 (14)c	***
Fertilizer type	Slurry + mineral	Farmyard manure	Farmyard manure	Farmyard manure	n.a.
Extensive management (no years)	–	10 (4.7)a	10 (5.8)a	33 (6.9)b	***
Grassland age (years)[2]	26 (35)a	82 (32)b	93 (25)b	100 (0)b	***
Plant species richness (no 25 m^{-2})	8.0 (2.4)a	14.8 (2.5)b	19.7 (3.1)c	22.6 (4.4)c	***
Soil moisture content (Vol%, 0–10 cm)	39.3 (9.1)b	46.7 (12.4)a	47.6 (10.4)a	51.8 (9.1)a	**
Soil penetration resistance (MPa 0-10)	0.46 (0.1)a	0.35 (0.1)b	0.39 (0.1)b	0.37 (0.1)b	*
pH_{KCl}	5.7 (0.4)c	5.3 (0.4)b	5.4 (0.4)b	4.9 (0.3)a	**
Earthworms (no m^{-2})	1015 (504)	869 (466)	801 (508)	774 (515)	ns
Adult Earthworms (no m^{-2})	332 (230)a	237 (168)ab	209 (186)ab	164 (118)b	*
Earthworm biomass (g m^{-2})	190 (107)a	133 (80)ab	124 (80)ab	106 (60)b	**
Individual biomass (g $worm^{-1}$)	0.20 (0.1)	0.16 (0.1)	0.18 (0.1)	0.16 (0.1)	ns
Epigeic earthworms (no m^{-2})	180 (142)	178 (175)	106 (83)	96 (80)	ns
Endogeic earthworms (no m^{-2})	820 (460)	687 (355)	679 (447)	675 (491)	ns
Anecic earthworms (no m^{-2})	15.3 (24.4)a	4.1 (9.4)ab	5.7 (12.1)ab	2.1 (7.1)b	**
Leatherjackets (no m^{-2})	102 (160)	58 (70)	24 (35)	31 (42)	ns

*P<0.05; **P<0.01, ***P<0.001. Grasslands with an age since last grassland renewal above 100 were set at 100.

Earthworms are an important food source for meadow birds. The average number of worms per square metre was very high, ranging from 774 to 1015 for the four grassland types. Earthworm biomass averaged between 106 and 190 grams per square metre for the four types (Table 1). This exceeds the specified minimum standard of 60 g m^{-2} and the critical threshold for the black-tailed godwit (*Limosa limosa*), which is 25–30 g m^{-2} (Van der Weijden and Guldemond, 2006). Thus, food abundance for meadow birds seems to be sufficient in all management types, and was highest in INT. However, in intensively managed grasslands, soil moisture was the lowest and soil penetration resistance was the highest (Table 1), which may negatively affect availability of earthworms for meadow birds in dry conditions.

Conclusion

Our results show that the effects of grassland management intensity and N-fertilization on earthworm abundance and biomass were positive. The results of the abundance of leatherjackets showed a similar (non-significant) tendency as for earthworms. Earthworm and leatherjacket numbers in INT managed permanent grasslands were higher or equal compared to EXT managed grassland, but the availability to grassland birds may be lower, especially in dry conditions.

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