The habitat preference of root voles in Nieuwkoopse Plassen, the Netherlands

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Abstract: The root vole (*Alexandromys oeconomus arenicola*) is one of the species for which Nieuwkoopse Plassen & De Haeck (Provinces of Zuid-Holland and Utrecht, the Netherlands) has been designated as a Natura 2000 site. This subspecies is endemic to the Netherlands and can only be found in five regions in the country. The decline of root vole populations is mainly due to the loss of suitable habitat and to competition with other vole species, especially the field vole (*Microtus agrestis*), the common vole (*Microtus arvalis*) and bank vole (*Myodes glareolus*). The main research questions were: what is the relation between vegetation type, type of land management and location within the field on the abundance of root voles in Nieuwkoopse Plassen & De Haeck? It was expected that root voles would prefer extensively managed reed vegetations and rough wet grasslands and that root voles prefer sites close to the edge, as opposed to the centre of fields. It was found that lowland hay meadows, a habitat type that has almost completely disappeared in recent years, and helophytes vegetation are important vegetation types for root voles. Fen woodlots and grasslands dominated by velvet grass (*Holcus lanatus*) or ryegrass (*Lolium perenne*) were found to have the lowest abundance of root voles. Winter mown vegetation where clippings were burnt held higher numbers of root voles, whereas hayfields that were mowed in mid June and grazed for some time before and after mowing were not good for root voles. Within the fields root voles preferred locations close to the edge over central locations.

Keywords: root vole, *Alexandromys oeconomus Arenicola*, land management, vegetation, habitat preference.

Introduction

In order to protect endangered habitat types and wild flora and fauna in Europe the Member States of the European Union introduced the Habitats Directive in 1992. This obliged Member States throughout Europe to designate Natura 2000 sites to ensure the survival of Europe's most valuable and threatened species and habitats. In the Netherlands each Natura 2000 area has a Designation Order that specifies the conservation objectives, derived from the Habitats Directive (Ministry of Agriculture, Nature and Food Quality 2006).

One of these Natura 2000 sites is the Nieuwkoopse Plassen & De Haeck (hereafter Nieuwkoopse Plassen). This area is located in the provinces of Zuid-Holland and Utrecht and measures 2028 ha (figure 1). The Nieuwkoopse Plassen is a fen marsh, featuring different stages of fen succession and is characterized by nine habitat types and contains eight valuable or threatened species. Some of these habitats, such as transition mires and quaking bogs, are very rare and vulnerable, and provide an important habitat for rare flora and fauna.

One of the conservation objectives for the

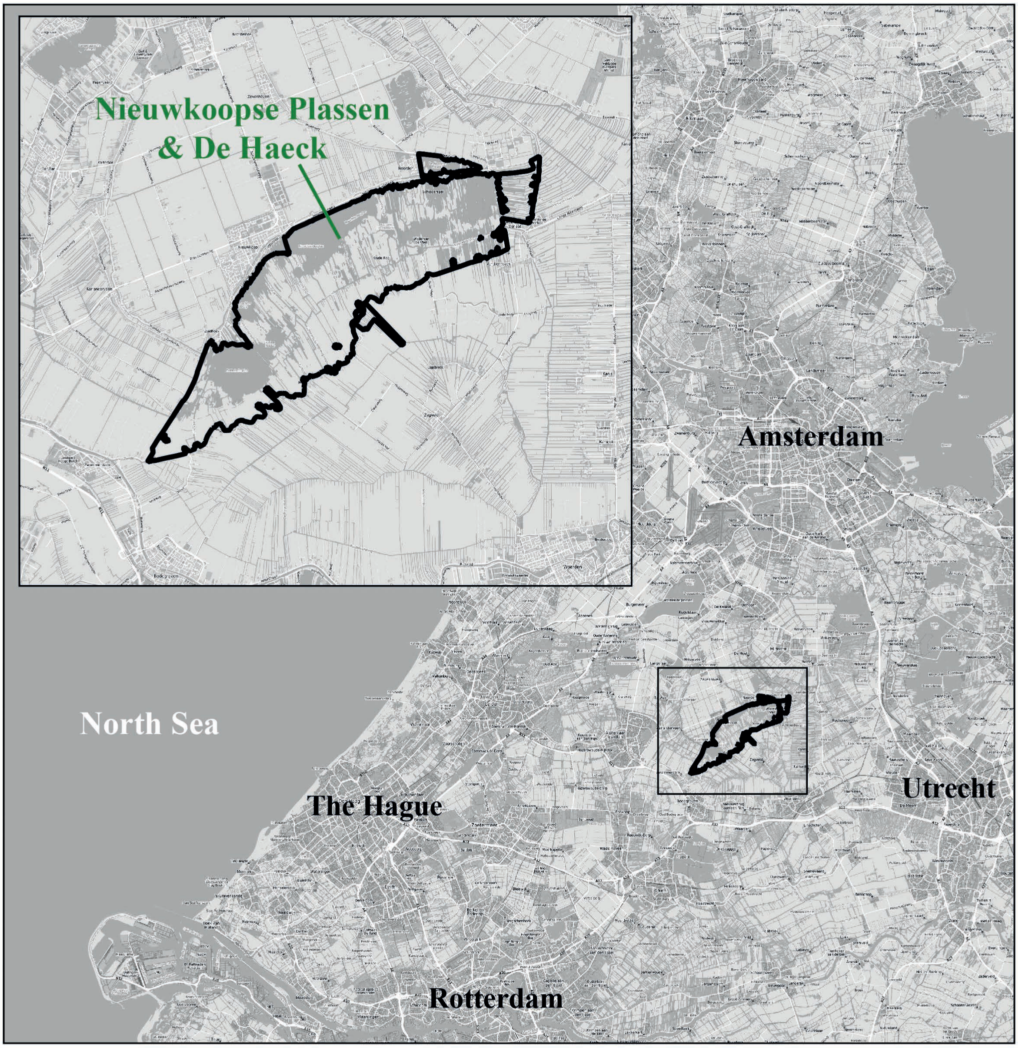


Figure 1. Location of the Natura 2000 site of the Nieuwkoopse Plassen & De Haeck, between Rotterdam and Amsterdam, the Netherlands.

Nieuwkoopse Plassen is the preservation of the size and quality of the habitat in order to preserve the population of the root vole (*Alexandromys oeconomus arenicola*) (Provincie Zuid-Holland 2015). This sub-species of the root vole is endemic to the Netherlands and can only be found in five regions: Texel, the Frisian lake district, the northern part of Noord-Holland, Nieuwkoopse Plassen and the Delta region in the southwest. As this subspecies is endemic, the Netherlands has a big responsibility to protect it. Since 1950 the root vole in the Netherlands has declined by 35% (van Norren et al. 2020). This decline is mainly due to the disappearance of suitable habitat, a lack of dynamic water level management (Bergers & Nieuwenhuizen 2000) and competition with other voles, mainly the field vole (*Microtus agrestis*), the common vole (*Microtus arvalis*) and the bank vole (*Myodes glareolus*) (Drees 2003, La Haye et al. 2004, Mostert & Bekker 2019). In areas where root voles compete with these other species, they are almost exclusively found in reed and grass vegetation at the waterside (La Haye et al. 2001). Management measures such as mowing, grazing and sod cutting can cause a decline in the root vole population (Bergers et al. 1998a), even though they also have some benefits for the survival of the root vole population as they prevent the encroachment of shrubs. Yet, at the same time short vegetation enhances predation risk. Grazing can lead to the trampling of their burrows and nests (Jacob 2008).

Further research into the habitat preference and dispersal of root voles in areas with competing vole species has showed that root voles prefer wet nutrient-poor grasslands, reeds and thickets (Bergers et al. 1998b). Research on root voles in the province of Noord-Holland, showed that species rich reed lands and wet extensive managed grasslands had the highest abundance of root voles (Nijhof & Van Apeldoorn 2001). This is in line with the diet of root voles, which mainly consists of young shoots of reed, sedge and grass (Tast 1982). In 2016 research was done on the habitat preferences of root voles in the Nieuwkoopse Plassen. This research showed that root voles have a preference for winter mown reed lands and extensively grazed grassland with common rush (*Juncus effusus*) (Zielman 2016, Van Schie & Zielman 2019).

The main research questions for this research were: what is the relation between the abundance of root voles in fields in the Nieuwkoopse Plassen and: 1. Vegetation type. 2. Type of land management. 3. Location in the field? In addition, we analyzed whether the potential living area for the root voles in the Nieuwkoopse Plassen has increased or decreased and whether the number of root voles caught has increased or decreased over the course of the years.

The first hypothesis was that root voles would prefer reed vegetation and wet, structure rich grasslands. Secondly it was expected that extensive land management would be preferred over intensively managed land. Thirdly it was expected that root voles prefer sites close to the edge, as opposed to the centre, of a field, because they prefer wetter conditions than other vole species so this is their preferred habitat when competing voles are present. Lastly it was expected that the potential suitable habitat for the root voles would have increased between 2009 and 2019 due to a change towards less intensive management, creating more suitable places for them to hibernate during winter.

This study started in 2010. Results of the period 2010-2016 have already been published (see van Schie & van Veen 2012, van Schie & Zielman 2019), but in one more year (2018) field data were collected and, more importantly, the vegetation was mapped again in 2019. The recent vegetation map allowed a better analysis of the relation between vegetation and the abundance of root voles.

Materials and methods

Data gathering

Data on the abundance of root voles in the Nieuwkoopse Plassen were collected every year between 2010 and 2016 and again in 2018. The animals were caught with Longworth live-traps placed in transects about hundred metres long. Approximately every ten metres a pair of traps was placed. After two days in the field when the bait and the trapping mechanism were blocked, the traps were activated for four days and checked twice a day for voles. Whenever a root vole was trapped it was taken out and, when a vole was caught for the first time, a small piece of fur was cut near the tail. This allowed us to ensure that each individual was only counted once in the data analysis, and to exclude recaptures. The captured root voles were attributed to the trap transects, as it was not specified in which exact trap the voles were caught.

Vegetation was mapped according to a standardized protocol (BIJ12 2016). These vegetation

Table 1. Table showing the number of transects that were monitored in each year, with a total of 259 transects combined in which root voles were caught in 126.

Year	Total number of transects	Number (and %) of transects with root voles
2010	45	38 (84)
2011	39	22 (56)
2012	31	13 (42)
2013	19	16 (84)
2014	23	9 (39)
2015	41	15 (37)
2016	25	8 (32)
2018	36	5 (14)
Total	259	126 (49)

maps are a digital visualisation of where different vegetation types can be found within a nature area. For this analysis vegetation maps from 2009 and 2019 were available (Damm & Van 't Veer 2010, Langbroek et al. 2019). It was decided to link capture data between 2010 and 2014 to the 2009 vegetation map and data from 2015, 2016 and 2018 to the vegetation map of 2019, under the assumption that these maps would show most similarity with the existing vegetation in the corresponding years.

The management regime that was used on the different fields in the Nieuwkoopse Plassen was mapped every year. To determine what management regime should be linked to which root vole trapping year we checked in which season the trapping was performed. The root vole catches were linked to the management regime that was in use before the catching moment, in either the same year or previous year.

Data analyses

To determine to what vegetation and / or management type a recorded root vole should be attributed, a buffer of five metres was put around the transects using QGIS (QGIS development team 2021). This buffer was made because it was possible that there was more than one type of vegetation or management per transect. A buffer of five metres was chosen to exclude surface area on the other side of ditches and to avoid overlap between transects located near the edge and in the centre of fields. The buffer was thereafter used to calculate the number of Root Voles per transect per Vegetation type or Management (RVVM) (equation 1).

Here *N* represents the number of unique root voles captured per transect over the four days, with the surface area measured in square metres. No set surface area can be given as this differed per transect, as due to unevenness in the fields not all transects were exactly one hundred metres long.

Statistical analyses

As normality was proven, a One-Way-ANOVA was used to test the relationship between land management type and the number of root voles. If a difference was found a post-hoc Tukey test was run. To test the relation between vegetation type and the number of root voles a Kruskal-Wallis test was used, as in this case normality was not proven, and when a difference was found a post hoc LSD test was run. To check whether more root voles were found close to the edge or at the centre of fields a *t*-test was used, as normality was proven. To test whether the number of root voles caught changed over the course of the years a linear model was used. For all these tests the independent variables were vegetation type, management type, location in the field or the years and the dependent variable was the number of root voles per transect. The statistical analyses were performed using R statistics (R Core Team 2013).

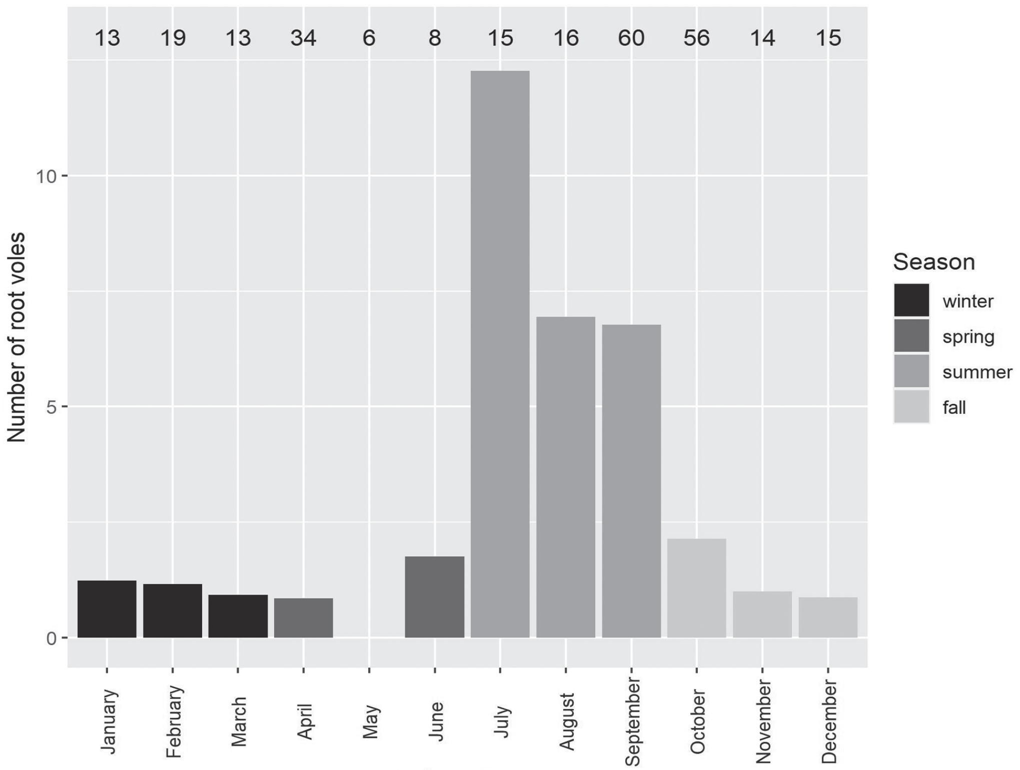


Figure 2. Graph showing the mean number of root voles (y-axis) and the month of the year in which they were caught (x-axis).

Temporal analyses

After the statistical analyses, the results were processed to perform temporal analyses. First, both the vegetation type and management type were divided into groups according to the outcome of the statistical analyses. Afterwards a score was given to each group, where a higher score means a more suitable area for root voles. These scores are based on the significant differences between the vegetation types and management types. For vegetation, a score between one and five was used and for management a score between one and three. Four maps in total were made according to these scores, two maps for vegetation and two maps for management type according to the mappings of 2009 and 2019. We then analyzed whether the potential habitat increased or decreased between 2009 and 2019 as a result of changes in vegetation type and management regime.

Results

Root voles were surveyed in a total 259 transects between 2010 and 2016 and in 2018. The lowest number of transects was in 2013 (19) and the most transects were laid out in 2010. Root voles were caught in 126 transects in total (table 1). The transects were not all monitored in the same months each year, but all months have at least six transects. The transects were most frequently monitored in September and October (60 and 56 transects respectively; see figure 2). This figure also shows that the summer months (July-September) had the highest mean number of root voles. It was therefore decided to run all the analyses twice, once

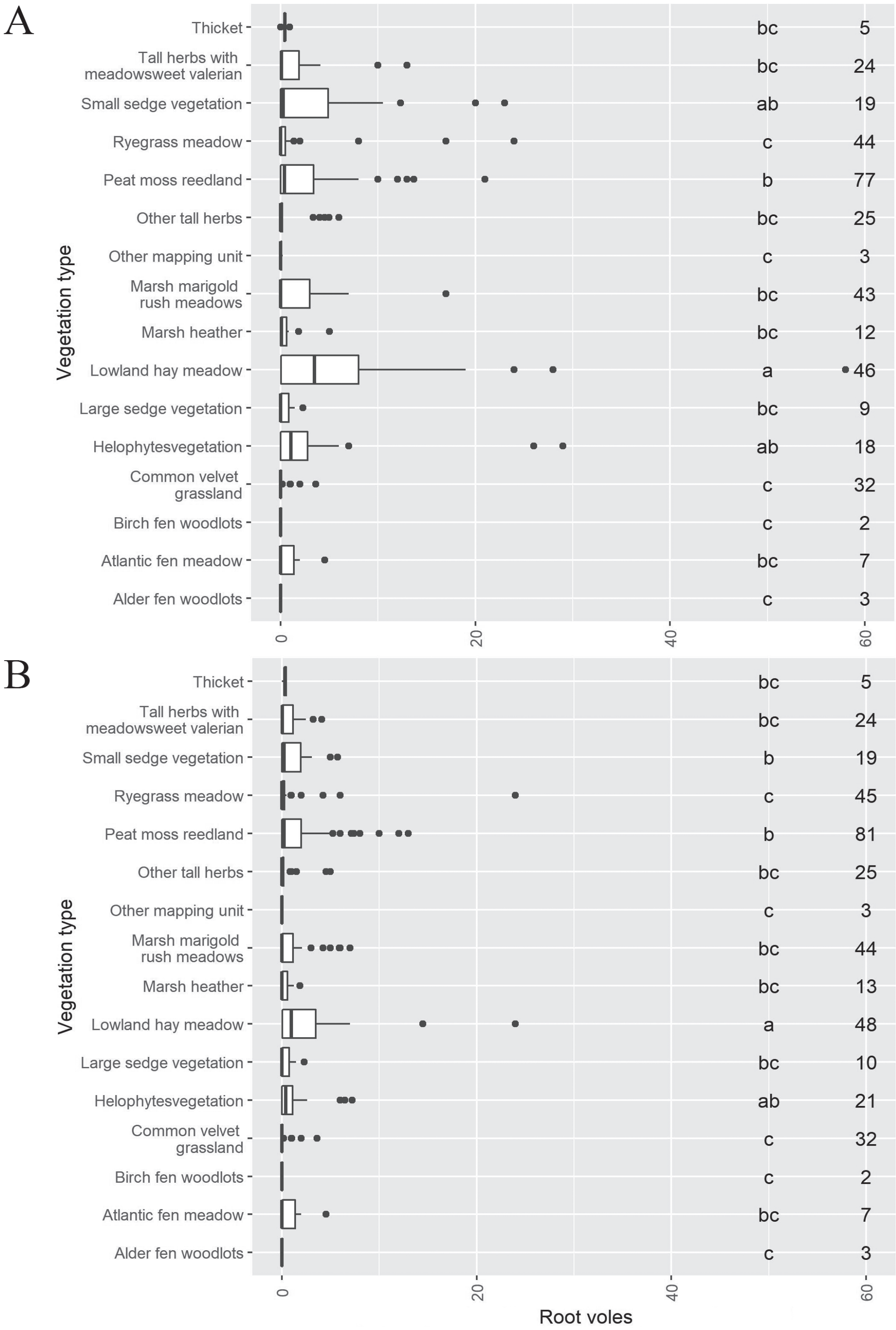

A
B
Vegetation type
Thicket
Tall herbs with meadowsweet valerian
Small sedge vegetation
Ryegrass meadow
Peat moss reedland
Other tall herbs
Other mapping unit
Marsh marigold rush meadows
Marsh heather
Lowland hay meadow
Large sedge vegetation
Helophytesvegetation
Common velvet grassland
Birch fen woodlots
Atlantic fen meadow
Alder fen woodlots
bc 5
bc 24
ab 19
c 44
b 77
bc 25
c 3
bc 43
bc 12
a 46
bc 9
ab 18
c 32
c 2
bc 7
c 3
bc 5
bc 24
b 19
c 45
b 81
bc 25
c 3
bc 44
bc 13
a 48
bc 10
ab 21
c 32
c 2
bc 7
c 3
0
20
40
60
Root voles

Table 2. Total area of habitat suitable for root voles (by category) according to the vegetation maps of 2009 and 2019. c is low suitability, a high.

Score	Year	Area (ha)	Percentage	Score	Year	Area (ha)	Percentage
1 (c)	2009	452.57	38.13	1	2019	602.54	49.08
2 (cb)	2009	413.63	34.85	2	2019	496.56	40.44
3 (b)	2009	113.85	9.59	3	2019	84.56	6.89
4 (ab)	2009	66.83	5.63	4	2019	44.11	3.59
5 (a)	2009	139.94	11.79	5	2019	0	0
Total	2009	1186.82	100	Total	2019	1227.76	100

with the normal data and one with corrected data. For the corrected data the number of root voles caught in the summer months was divided by four, as in the summer months on average, about four times the number of root voles were caught.

Vegetation

A Kruskal-Wallis test showed that there was a relationship between vegetation and the number of root voles. This was found for the uncorrected data ($X^2_{(17)}$ =52.57; P<0.001) and the corrected data ($X^2_{(17)}$ =42.631; P<0.001). The *post-hoc* analysis for the uncorrected data showed that lowland hay meadow was the vegetation type where most root voles can be found, closely followed by helophytes vegetation and small sedge vegetation. It also showed that grasslands dominated by velvet grass or ryegrass, birch and alder woodlots were least likely to be suitable for root voles (figure 3). The corrected data showed a difference for small sedge vegetation, for the corrected data it no longer belongs to group a but to group b (see below for explanation).

Figure 3. Boxplot A shows the uncorrected data with the mean, standard deviation and outliers for root voles found per vegetation type, where the number of root voles is measured by the root voles caught per transect. The letters show the vegetation types by category. The numbers behind the letters show the frequency in which vegetation type were found in at least part of a transect. Boxplot B shows the corrected data. Here the numbers changed, as with the corrected data the transects where separated by the month and there was some overlap between locations.

After the statistical analyses, the vegetation scores were assigned to different groups. Figure 3 shows letters, which form the different groups. Group a (just the lowland hay meadows), which had the highest abundance of root voles was assigned a score of 5 and group c had the lowest number of root voles and was assigned a score of 1. It was found that between 2009 and 2019 score 5 habitats, where most root voles resided, disappeared from the Nieuwkoopse Plassen and scores 3 and 4 also decreased (table 2).

Land management

A One-Way-ANOVA, on both the uncorrected and corrected data ($F_{(12)}$ = 2.095, P=0.018 and $F_{(12)}$ = 2.242, P=0.010 respectively) showed that the types of management had a significant effect on the number of root voles present. The post-hoc analysis showed that areas that were mowed in the winter, after which the mown vegetation was burnt, had a higher number of root voles than areas that were mown once a year, which had the fewest root voles (figure 4). The corrected data showed a somewhat different picture, here the main difference was between 'conventional farming' and 'meadows, which were mowed around June 15 and grazed for some time before and after mowing'. These meadows were assigned to group b and areas where encroaching trees

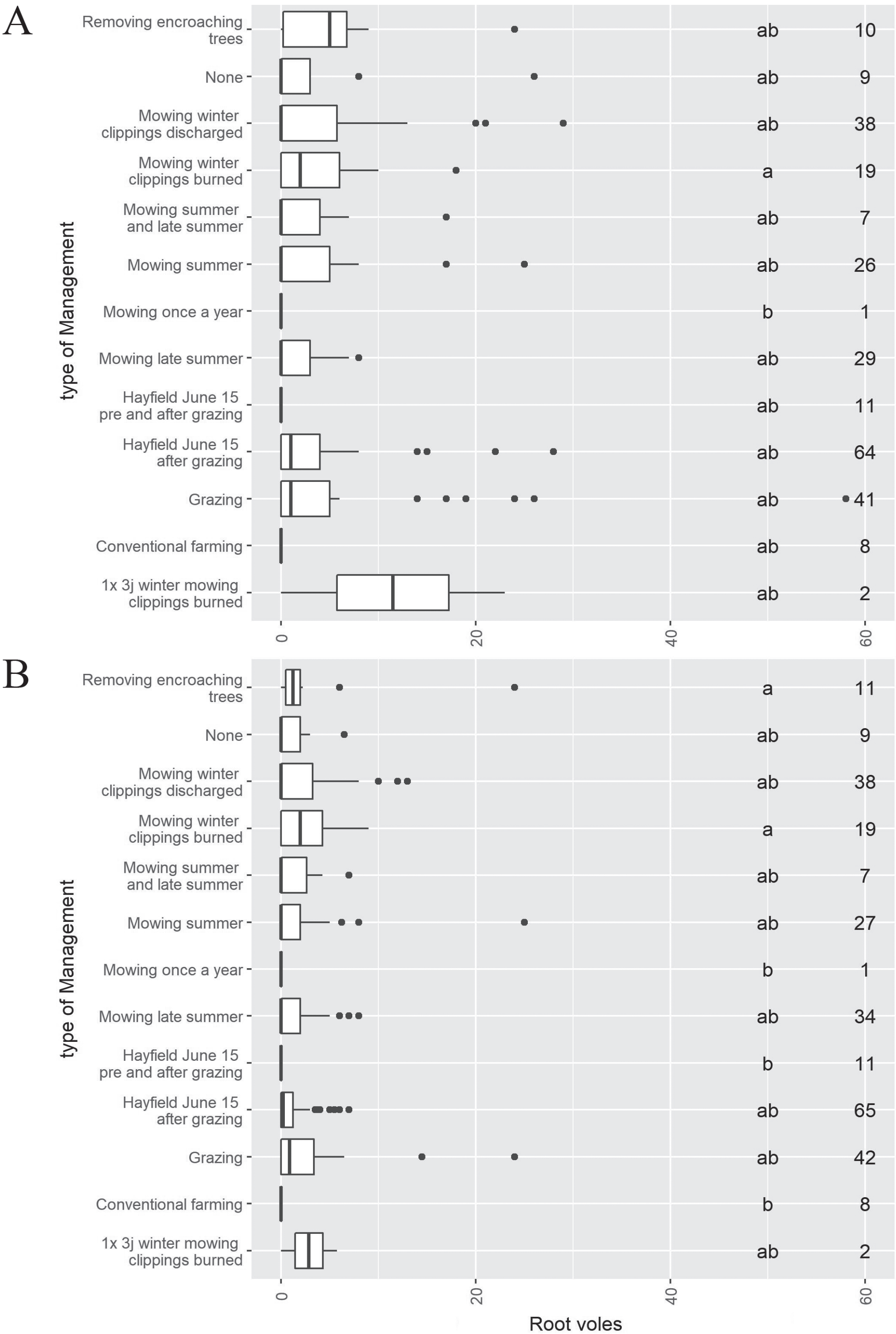

A
B
Removing encroaching trees
None
Mowing winter clippings discharged
Mowing winter clippings burned
Mowing summer and late summer
Mowing summer
Mowing once a year
Mowing late summer
Hayfield June 15 pre and after grazing
Hayfield June 15 after grazing
Grazing
Conventional farming
1x 3j winter mowing clippings burned
type of Management
Root voles
0
20
40
60
ab 10
ab 9
ab 38
a 19
ab 7
ab 26
b 1
ab 29
ab 11
ab 64
ab 41
ab 8
ab 2
a 11
ab 9
ab 38
a 19
ab 7
ab 27
b 1
ab 34
b 11
ab 65
ab 42
b 8
ab 2

Table 3. Total area of land (by category of suitability for root voles) under different types of management. b is low suitability, a high.

Score	Year	Area (ha)	Percentage	Score	Year	Area (ha)	Percentage
1 (b)	2009	36.09	6.05	1	2019	40.12	8.18
2 (ab)	2009	312.46	52.41	2	2019	437.01	89.07
3 (a)	2009	247.69	41.54	3	2019	13.52	2.76
Total	2009	596.24	100	Total	2019	490.65	100

had been removed were assigned to group a.

A small adaptation was made after the statistical analyses of land management to assign land to different categories. Land on which trees had been removed was allocated to group a, as this category of land had a higher mean average of root voles than winter mown grasslands, which was already allocated to group a. Land that was mowed once a year, land that was managed with no maximum grazing density and no restrictions on management was put into group b together with the hay meadows with grazing before and after mowing, because no root voles were found on land managed according to these strategies. Group a was given a score of 3, group ab was given a score of 2 and group b was given a score of 1. Here score 1 represents the least attractive option for to root voles and a score of 3 the most attractive. We found that between 2009 and 2019 almost all the areas with a score of 3 disappeared (table 3).

Location of the transect in the field

Transects were almost equally divided between being near the edge of a field (n=129) or in the centre (n=127). After performing t-tests on the uncorrected and corrected data it was found that root voles prefer sites close to the edge, as opposed to the centre of fields in habitats where there were competing voles (t=3.024, P=0.003 and t=2.551, P=0.011 respectively).

Figure 4. Boxplot A shows the uncorrected data with the mean, standard deviation and outliers for root voles found in each type of land management per transect. The letters show the different types of management regime by category. The numbers next to the letters show the number of times that these management types occurred within a transect. Boxplot B shows the corrected data.

Root vole abundance

As it was found that the potentially best habitats for root voles, both in terms of vegetation and land management had declined, or even disappeared entirely between 2010 and 2018 we also tested to see if the number of root voles caught also had declined in this period. Using a linear model, we found that the number of root voles caught declined for both the uncorrected data (R^2=0.039, P=0.015) and the corrected data (R^2=0.040, P=< 0.001) (figure 5).

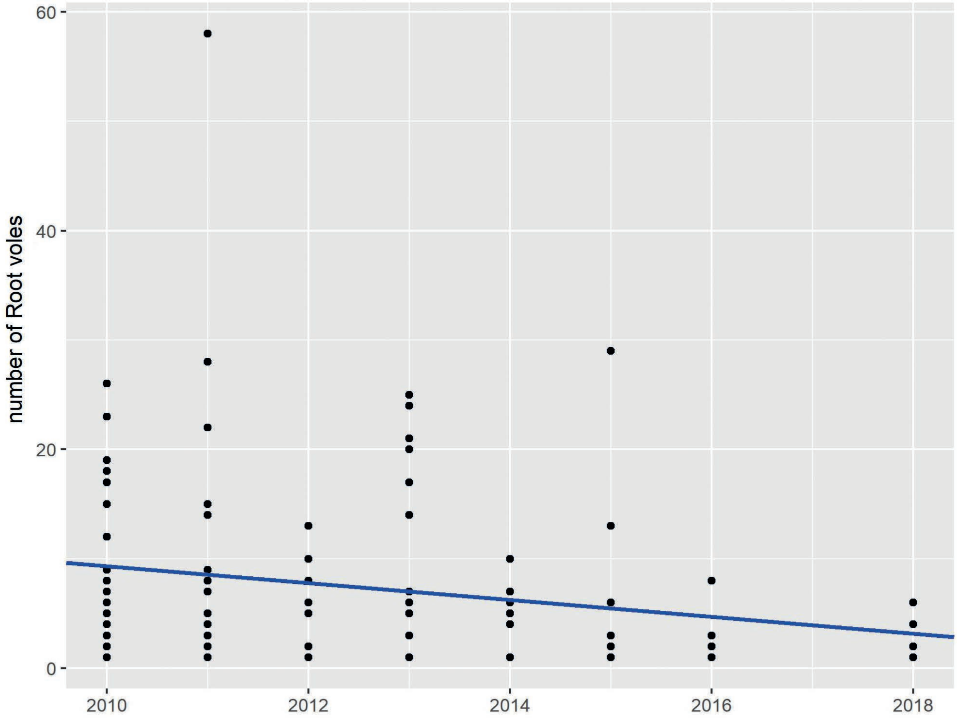
Discussion

In the interpretation of the results it needs to be born in mind that in this study the field vole, a major competitor of the root vole, was not recorded in the Nieuwkoopse Plassen. In areas where the field vole is present the root vole can be limited to fewer vegetation types because of competition (Bergers et al. 1998, La Haye et al. 2001).

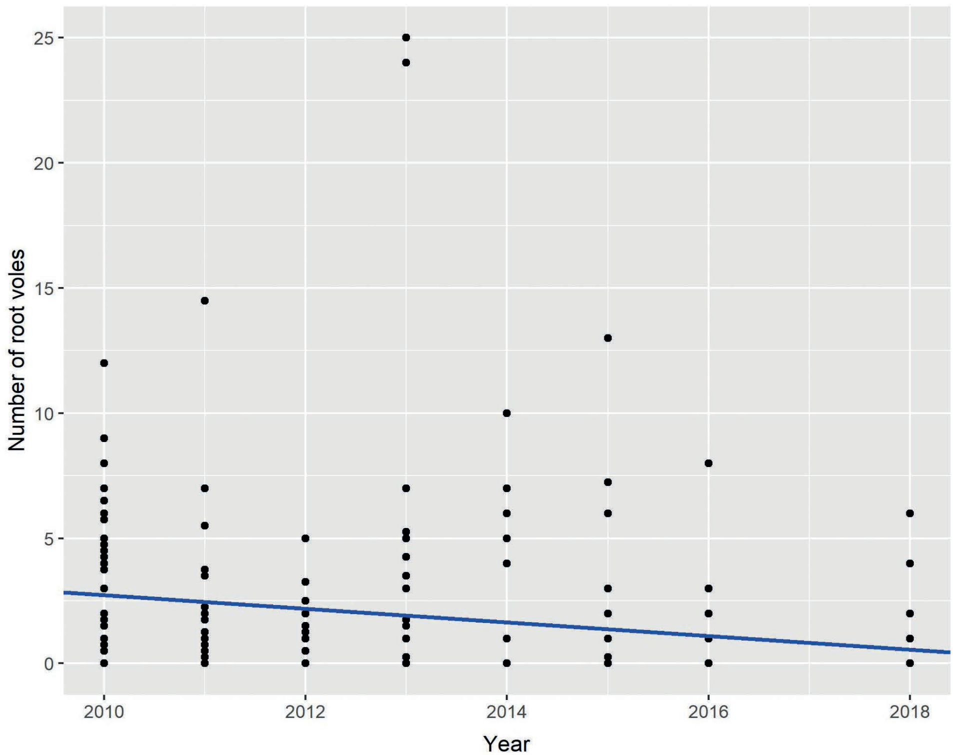
Vegetation

The vegetation analyses showed that lowland

A


number of Root voles
60
40
20
0
2010
2012
2014
2016
2018

B


Number of root voles
25
20
15
10
5
0
2010
2012
2014
2016
2018
Year

hay meadows are the best vegetation type for root voles in the Nieuwkoopse Plassen. These meadows mainly consisted of meadow foxtail (*Alopecurus pratensis*) and false oat-grass (*Arrhenatherum elatius*). This is a vegetation type that occurs mostly on (semi)wet and nutrient rich soils. Previous research also showed that root voles prefer wet areas, but in those studies the wet areas were nutrient poor (Bergers et al. 1998b, Nijhof & van Apeldoorn 2001). However, two of the five regions of the Netherlands where root voles can be found (the Delta region and Texel) are generally nutrient rich. This difference in nutrient richness might not be that important because young shoots of sedge and grasses, which root voles eat, can be found in both nutrient rich and nutrient poorer soils. Another important factor for the root voles is structural variation in the vegetation (BIJ12 2017). This is something that lowland hay meadows can have when plant species, such as common rush and rough bluegrass (*Poa trivialis*), are present but without these plants the meadows can lack structural variety. The presence of common rush has been shown to be an important factor for root voles in previous research (Zielman 2016, van Schie & Zielman 2019). In addition, lowland hay meadows are known to be quite wet and can even temporarily flood. Root voles prefer wet or even temporarily flooded meadows , although flooding rarely occurs in the Nieuwkoopse Plassen. It was not a surprise that helophytes vegetation was the second-most preferred vegetation. This is a wet and structure rich vegetation in which other vole species, that could be competitors with the root voles, usually do not live. It was also no surprise that fen woodlots scored badly, as very little food is available there and the opportunity to make burrows is almost non-existent.

Figure 5. Graph A shows the uncorrected data with the transects in which root voles were captured. Each point represents one transect with the corresponding number of root voles. There is no data for 2017, as no transects were laid out that year. Graph B shows the corrected data.

Land management

The analysis for the best management strategy showed that mowing in winter and then burning the mown vegetation yielded the highest number of root voles per transect. Burning mown vegetation might sound counter-productive in terms of creating a suitable habitat but it reduces the competition with other vole species, mainly because root voles live in burrows and are thus mostly safe from fire. Another reason why this management strategy might be good is because a smaller machine can be used for the mowing and no machine has to be used to remove the mown vegetation as these are burned. Using a smaller machine might mean that the burrows of root voles have a higher chance of remaining intact due to there being less disturbance.

It was also not surprising that hayfields which were mowed around June 15 with pre and post grazing for some time were bad for root voles. This management strategy means that there are three disturbances every year, the first of which is grazing in spring, after which the area is mowed around June 15th and then grazed again. This also means that the vegetation is short all the time. Short vegetation in turn increases the risk of predation, not just upon root voles, but on voles in general (Jacob 2008). The same goes for conventional farming in the Nieuwkoopse Plassen, in which farmers are mostly free to manage their land as they like, providing that they comply with general laws and regulations. This means in practice that the land is used intensively and due to this the vegetation is usually short and lacks structural variety .

A management strategy that could possibly have a positive effect on the root vole population is dynamic water level management. By manipulating the water level, the area can be left wetter for a longer period in spring, which would dislodge the field vole. Another added benefit is that small islands can be formed when the water level is gradually lowered. As root voles are better able to swim than other voles, they can settle in these areas earlier than other vole species (Vandenbosch et al. 2009). Root voles are also better adapted against cold than other vole species and hence thrive better close to water. Van Wijngaarden & Zimmermann (1965) described that the ideal habitat of the root vole is the place where water meets land.

The location of root vole in fields

More root voles were caught along the edge of fields than in the centres. The edges of fields are usually wetter or might even contain a water ditch, which suits the root voles, and would be more nutrient rich, especially in peat moss areas, which usually means more available food. The edges in agricultural areas are also richer in structure, but not necessarily richer in nutrients. Moreover, both the management and vegetation is, in most cases, different near the edge of a field than in the centre. This difference is mainly that 5-10% of the reeds near the edge are not mowed, to allow animals to find shelter to get through the winter, which can also serve as a shelter or foraging area shortly after mowing.

Changes in habitat availability

There were big changes in the potentially suitable habitat between 2009 and 2019, both regarding the land management type and the vegetation type. The group of vegetation types with the highest abundance of root voles (lowland hay meadows) was completely gone in 2019 (table 2) and for land management the categories with the highest abundance decreased by almost 90% in the same period (table 3). The lowland hay meadows disappeared to a change in management. In the last couple of years of the survey more fields in the Nieuwkoopse Plassen were mowed or grazed, which was done to allow more opportunities for the endangered habitat types and plant species that are, like root voles, protected by the Habitats Directive. More focus on other conservation objectives also contributed to the decrease in suitable habitat: burning mown vegetation no longer takes place in the Nieuwkoopse Plassen because it has a large negative effect on almost all the other red list and target species.

Conclusions

The two most important vegetation types for root voles are lowland hay meadows and helophytes vegetation. Fen woodlots and grasslands dominated by velvet grass and ryegrass were found to be the least populated vegetation types in the Nieuwkoopse Plassen. Vegetation that was mowed in winter, and then burnt seemed to be positive for root voles. On the other hand, hayfields that were grazed for some time in spring and summer and mown around June 15 were not good for root voles. Root voles prefer locations close to the edge of fields over locations in the centre. Between 2009 and 2019 the potential suitable habitat for root voles in the Nieuwkoopse Plassen decreased substantially. We conclude that the combination of burning mowed vegetation and leaving vegetation at the edge of fields after mowing provides optimal habitats for root voles.

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Samenvatting

Habitatvoorkeur van de Noordse woelmuis in de Nieuwkoopse Plassen

De Noordse woelmuis (*Aleandromys oeconomus arenicola*) is één van de habitatrichtlijnsoorten voor het Natura 2000-gebied

de Nieuwkoopse Plassen & De Haeck. De ondersoort *arenicola* is een ondersoort van de Noordse woelmuis die alleen in Nederland voorkomt en in maar vijf regio's, wat de bescherming van dit type van de Noordse woelmuis extra belangrijk maakt. De achteruitgang van de Noordse woelmuis is vooral te wijten aan het verdwijnen van geschikt leefgebied en aan concurrentie met andere woelmuizen, met name de aardmuis, veldmuis en rosse woelmuis. De onderzoeksvraag was: wat is de relatie tussen vegetatietype, type beheer en locatie op het perceel met het voorkomen van de Noordse woelmuis in de Nieuwkoopse Plassen & De Haeck? De verwachting was dat Noordse woelmuizen een voorkeur hebben voor extensief beheerde helofytenvegetaties en ruige, natte graslanden. Ten tweede was de verwachting dat Noordse woelmuizen de locaties langs de oevers van een perceel prefereerden ten opzichte van het midden van een perceel, omdat de oevers natter zijn. Uit de analyse bleek dat vossenstaart-, glanshaverhooilanden en helofytenvegetaties het belangrijkst waren. Ook bleek dat er in broekbossen, witbolgraslanden en raaigrasweiden de minste Noordse woelmuizen werden gevonden. Het beste beheertype voor de Noordse woelmuizen was het maaien van de vegetatie in de winter, waarna het maaisel werd verbrand. Beheer waarbij gemaaid wordt rond 15 juni en begrazing daarvoor en daarna was het minst geschikte beheertype.

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