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The Effects of Different Linear Habitats on Small Mammal Abundance and Diversity within Lowland Agricultural Landscape

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Research Article

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ABSTRACT

Farmland biodiversity has declined due to changes in agriculture. Such changes have also seen the increase in field sizes which reduces the amount of linear boundary features which are important for habitat for many small mammal species. Certain characteristics of linear boundaries may influence small mammal species abundance and diversity due to the provisions of food, shelter and their role in species dispersal. The aim of this study was to compare two different linear features comprising of different features and to observe which of these certain features affects different small mammal species. The two linear features compared were an established hedgerow, some 170 metres in length with a width of two metres and a compiled woody fence feature which was only 30 metre in length with a width of 0.5 metre. Data was collected over a month by the use of Longworth traps that were placed five metres apart along the trapping line, all small mammals caught were recorded based on species, sex and weight. All the data collected was analysed in Microsoft Excel and Past statistics software. The overall unique species homogeneity was calculated by the use of Chi-squared, as well as both the Simpson and Shannon diversity indexes being calculated too. Species sex and weight were analysed by the use of the Mann-Whitney U test. Overall, three small mammal species (Wood Mouse, Bank Vole and Yellow- Necked Mouse) were caught during this study. All three of these species were caught in the wood fence feature however just wood mouse was caught in the hedgerow. Unique individual capture was found to be little over three times higher in the wood fence feature than the hedgerow and the overall abundance and diversity found at the wood fence feature habitat was found to be statistically significant (P=0.0264) compared to the established hedgerow while species weight comparisons were statistically insignificant (P=0.4). Results from a trapping density showed the correlation between a particular characteristic of the linear features and the ecology of certain small mammal species. During the study the hedgerow gradually lost vegetation due to plant phenology this factor didn't affect wood mice but may be the explanation why Bank Voles and Yellow Necked Mice were absent since they are known to be negatively influenced by increased numbers of gaps present. Increased trapping density was caught on points with higher levels of low-lying dense vegetation and provisions of food. In Conclusion, the wood fence feature had greater abundance and diversity of small mammals and had characteristics which are beneficial and can be utilized in the conservation of these species.

INTRODUCTION

Agricultural intensification and landscape changes

Global food demands are expected to double from current 20th century levels by 2050 [1] to manufacture food to keep up

with global population increases [2,3]. Balmford [4] states that developing countries agricultural land area may need to increase by an estimated 25% to meet these demands.

Throughout and succeeding the Second World War, agricultural policy changed and focused primarily on maximising food production to feed the growing human population. However, this consequently resulted in an extraordinary level of agricultural intensification supplemented by economic grants guaranteeing prolonged price stability throughout the second half of the 20th Century [5]. This intensification has caused a dramatic reduction in landscape diversity. Since 1945, a 65% in farm numbers and 77% decline in farm labour has occurred along with a near fourfold yield increase [5].

Intensification of agricultural practices is considered as the human appropriation level of terrestrial net primary production which the worldwide value is set to rise from 30%. This increase will have multiple effects, both on biodiversity [1,6-9] as well as on a spatial scale i.e. landscape management, land cover and crop [1]. Nevertheless, during the past century, the landscape change rate has accelerated worldwide. Possible reason for this is the rising spatial scale of the human food chain [1].

Agriculture now signifies the dominant land use throughout much of Western Europe [5], making up 70% of land use in the UK [10] and the crucial changes took place in the last 40 years in arable landscapes [4] including further autumn spreading of crops along with further effectual harvesting, extra in-version tillage and hay to silage alteration [4].

Farming operations have become more specialized while the use of machinery has greatly increased which has successfully made operations quicker and more efficient consequences have resulted in the removal of 50% of the hedgerow stock [5] Farming practises have differentiated across the United Kingdom, whereby the east of the UK is dominated by arable farming whilst grassland and livestock dominated the west although mixed farming and grass ley use has declined [5] In the lowlands, Boatman et al. [5] states there is a trend of larger, specialised farms with greater sized fields which have correlated with a reduction in non-crop habitat and fields margins (i.e. fewer hedgerows). This has had adverse effects on farm biodiversity [11].

Agricultural intensification impacts on biodiversity

Throughout much of the UK and Western Europe, agriculture represents the dominant land use of which a significant part of European biodiversity is associated [5]. Estimations are that 50% of all European species, including a number of endemics as well as threatened species, depend on agricultural habitats [5].

A revolution in agricultural practices was observed in the second half of the 20th Century, which surpassed any previous agricultural developments. These changes were brought about with the assistance of economic incentives and technological advances to increase farming productivity; this has resulted in rapid unprecedented agricultural intensification over the last 60 years in post-war Britain, North-West Europe and North America [6].

However these agricultural changes in recent decades have changed the arrangement of the landscape and structural communities of flora and fauna [5,12] causing extensive declines in biodiversity related to lowland farmland, including declines in species richness and abundance of taxa [5,6]. The changes in agricultural policy to maximise crop yield was thought to be responsible for these large declines in farmland biodiversity within the UK and North-West Europe [5]. Changes in landscapes i.e. transformations of other natural habitats into agriculture, especially via clearance of woodlands is one of the major stressors affecting biodiversity [13] both alone or working interactively with climate change [1].

As agriculture has become more specialized and intensified there have been both localized farm-scale and regional trends for crop diversity reduction [14-16] and as a result, has led to the decline in habitat diversity across the landscape; resulting in species diversity [6,16]. These modified ecosystems are characterised by high levels of anthropogenic disturbance and landscape homogeneity which in spite of these adverse conditions, species of all taxa can find ways to survive from significant adaptation levels [17,18]. Biodiversity declines have been particularly noticeable among the habitat specialists while much of the taxa still familiar and common on arable landscapes are habitat generalists [5].

Agricultural intensification, although has had a massive negative effect on farmland flora and fauna biodiversity, has also had harmful influences on ecological services of agricultural systems [19]. Ecological services such as nutrient cycling, carbon sequestration, water purification, soil structure and functioning, and pollution which rely on biodiversity within and beyond the agricultural ecosystems [19].

Agricultural intensification on small mammals: Many species of small mammals have become adapted to life around agriculture to live within agro-ecosystems [1,20,21]. However small mammal populations are known to widely fluctuate [23,24] and many small mammal species have had an observable decline on UK farmland [23-25] over the last 40 years, including Harvest Mice and Field Voles [23,24]. Anon [25] states that agricultural intensification is the cause of these declines as it has caused a loss of both suitable habitat and food provisions due to the increase in farming intensity and loss of traditional rotational farming systems.

Several studies have been conducted to discover the effects agricultural intensification has had on small mammal communities in terms of population abundance, species richness, and species diversity [1]. Some studies that analysed small mammal individual abundance, species richness, and species diversity found out those landscape structural complexities can be influential, however, these observed trends aren't consistent [1].

Agricultural intensification affects small mammal species communities in different ways [26]. Bank Voles are assumed to be influenced by pesticides drifting into field margins [27]. Field Voles are threatened by grazing pressure increase, rough grassland decline, linear feature e.g. (Hedgerow) removal and "marginal land" loss due to agricultural development [26,28].

There have been recognised tendencies linking greater species richness and diversity to less intensely cultivated landscapes. Silva et al. [29] found out that landscape structure and heterogeneity positively correlated with greater species richness while species diversity was positively correlated with increasing amounts of vegetative cover. However, Millan de la Pena et al. [30] and Michel et al. [31] found that relatively homogeneous land uses and agricultural intensification levels negatively affected species diversity but not richness, due to negative influences on rare and habitat specialist species and favouring habitat generalists.

Farming practice types can also facilitate landscape structure complexity effects on small mammal communities. Fischer et al. [32] compared the effects of conventional vs organic farming practices and discovered a significant increase in small mammal abundance, species richness and diversity in the conventional farming practice landscape while organic farming had a higher small mammal abundance.

Hedgerows and field boundaries

Definition: Defra [33] defines a hedgerow as any margin line or field boundary made up of trees or shrubs over 20 metres in length and under 5 metres wide between the major woody stems at the base, as long as that at one time the vegetation was more or less continuous. Features such as earth banks or walls can be included if they are associated with lines of trees or shrubs [33].

This definition comprises 'classic' shrubby hedgerows, tree lines, shrubby hedgerows consisting of trees and hedgerow gaps (where shrubby sections maybe under 20 metres long, but gaps are also under 20 metres) [33].

Status and trends: Hedgerows have had an observable decline over the last half a century [34] with a hedgerow network in the UK estimated around 500,000 miles in 1946 decreased to 236,000 miles by 1993. This loss has been connected to biodiversity decreases in agricultural habitats [4,11,35]. Changes in governmental policy have been a result of these declines, changes such as loss of grants for removal of hedges, legislation to protect 'important' hedgerows as well as the establishment of more incentives for hedgerow planting and management [11,36]. Due to the changes of these policies, the percentage of hedgerows protected by these regulations has increased from 23.8% to 41.8% (CPRE, 2010) but managed hedgerows have shown a decline in 1984-2007 which correlates to an increase in "relict" classed hedgerows during this period. Hedgerow management is important as it supports rich abundances of invertebrates, provision of habitat for a range of flora and fauna and be a foraging source for many species throughout the year [11].

Ecological importance: In some European countries, hedgerows and other linear features are protected by legislation [38] and are designated conservation priority habitat under the European Union Biodiversity Strategy [39]. Throughout several European countries, England included, agri-environmental schemes (AES) offer enticements for sensitive management of hedgerows [37,40,41], while the 1997 Hedgerow Regulation legislation in the UK limits the removal of hedgerows. Regardless of these actions over the decade to 2007, 6.2% of hedgerow length was lost in the UK, mostly due to hedgerows being under-managed and converting into "relict hedgerows" or lines of trees [42]. Also in 2007, UK hedgerows which were considered as existing in 'good condition' ; following criteria including having minimal vertical gaps, minimum 1m in height and a 1.5m width was only 48% [42]. In North-west Europe, hedgerow stocks qualities are also deteriorating as wildlife habitats due to contemporary hedgerow management practices [11]. These practices have been determined by the expensive costs of other traditional hedgerows management strategies such as hedge-laying, a lack of farm labour and the loss of conventional management knowledge and skills [11].

In the UK, habitat fragmentation is acknowledged as a significant negative influence and limiting factor for the dispersal of many species as well as a major risk to their survival [43]. Since the changes in farming landscapes resulting in agricultural intensification have resulted in a loss of suitable habitat, linear boundary features such as hedgerows have fast become considered as vital elements and contributors to agricultural landscape biodiversity conservation[43]. These linear features act as ecological corridors which have to potential to reduce the negative impacts caused by habitat fragmentation by allowing species dispersal between large patches of habitat [43-45].

Hedgerows also participate significantly in the role of biodiversity conservation within intensively managed landscapes through the provision of food and habitats or refuges for a varied range of flora and fauna species [46-48]. Furthermore, ecosystem services such as pest control [49] and pollination [50] are supported by hedgerows, which may perform as a dispersion system in upcoming adaptations to climate change [11,51].

The structural state and composition of hedgerows have clear-cut effects on its value as a wildlife habitat, with numerous taxa displaying positive relationships with a hedgerow structure consisting of dense woody vegetation and few gaps [11]. For instance, hedgerows with dense shrub layers have higher possibilities to support shade-loving perennial flora species used by bees [52] hedgerows with many vegetative layers are associated with high diversities of invertebrates [53]; gap numbers present in hedgerows have been negatively associated with Bank Vole (*Clethrionomys glareolus*) [43]and Yellow Necked mice (*Apodemus flavicollis*) Kotzageorgis and Mason, [54]; and hedgerows that are more open and structurally simple have higher bird nest vulnerability due to predation risk increase [11,47].

Conservation value can be affected by the hedgerows size, as width has been shown to be the key cause of hedgerow understory plant communities abundance and diversity [11,55], the incidence of numerous farmland bird species has been acknowledged as having a positive association to hedgerow width [56,57]. Hedgerows with tall, wide canopies have been greatly associated with species richness of Carabid and Staphylinid beetles [11,58].

Agricultural intensification on hedgerows

Since post-war in the UK, traditional crop rotations have declined and diverse agriculture has been lost and both arable and pastoral farming has become more specialised [4] as well as a substantial increase in field sizes utilised for intensive agriculture [59] and an increased utilisation of pesticides and fertilisers for maximum crop yield growth [4].

These agricultural landscape simplification, intensification and field size changes in the lowlands has resulted in an extreme decline in not just the amount of field margins [4] but also the linear features lengths over the last 20 years [60].

Agricultural intensification operations have been made quicker and more efficient by the use of machinery but this has had consequences resulting in an overall hedgerow stock removal of 50% [5]. This removal of hedgerow stock has affected biodiversity across many taxa from invertebrates to mammals [11].

Small mammals in arable landscapes

Species and importance: Anthropogenic arable landscapes provide habitat for approximately 40-54 species of terrestrial British mammals [27]. With reference to small mammals, of under <50g in weight, farmland habitat is dominated by four main species, the Wood Mouse (*Apodemus sylvaticus*), Bank Voles (*Myodes glareolus*; formerly *Clethrionomys glareolus*, Field Voles (*Microtus agrestis*) and the Common Shrew (*Sorex aranues*). Tattersall and McDonald [61] states that of these four species that the Wood Mouse is more diverse and abundant even though Harris et al. [23] claim Field Voles are estimated to be the most abundant of all these mammals, however, their distribution is inclined towards Scotland and Wales and declined in the south. There are six other regular small mammal species which can be found on arable landscapes, these include, the Harvest mouse (*Micromys minutus*), Pygmy Shrew (*Sorex minutus*), Yellow Necked mouse (*Apodemus flavicollis*), House mouse (*Mus musculus*), Water shrew (*Neomys fodiens*) and the Dormouse (*Muscardinus avellanarius*) [27].

Small mammal community abundance, diversity, richness trophic position and responsiveness are undervalued but make them a useful group ecologically; important for both their basic biodiversity value and their fundamental role as prey for both terrestrial and avian predators [21]. For instance, studies have shown that small mammals accounted for 18-32% of the diet of Pine Marten [62], 47% of the Wildcat [63] and up to 90% of the Weasel [64]. Since small mammals made up a vast majority of these biodiversity action plan (BAP) carnivores diet, it is apparent that small mammals play a huge ecological niche and therefore it is crucial that monitoring of their populations are active in order to contribute to the survival of these carnivores [26].

Small mammals also have the potential to play roles in tree generation in woodland and hedgerow networks by the consumption, storing and dispersal of seeds [65,66].

Habitat and distribution: Mice such as Wood Mice and Yellow Necked Mice are widely abundant and distributed in deciduous woodland and hedgerows particularly adjacent to agricultural land [26,67] across the UK with the exception of mountainous regions. However their home ranges vary, Wood Mice have a territorial range in woodland from 0.19-0.63/ha and 0.26-1.77/ha in farmland whereas the territorial range of the Yellow Necked Mice extends to around half a hectare [26].

In contrast to the mice, voles such as Bank Vole and especially Field Vole prefer thick field layers and scrub and hedgerows but can also be known to be found in young forestry plantations and mature woodland [54,68]f across mainland UK. Bank Vole territorial range is from 0.05-0.73 ha whilst the Field Vole territorial range is 100-1000m^2 [26,27].

Shrews e.g. the Common Shrew are also found in abundance across the UK mainland, where there is an occurrence of low-lying vegetation particularly reference to scrub, hedgerows and rough grass [69] similar to voles, but have fairly small home range territories (370-630m^2) [26].

Dietary requirements: Wood Mice are predominately granivorous [70], however, vegetal and animal remains are commonly found within the stomach content which recognises them as omnivorous [71]. Wood Mice are opportunistic feeders, eating what's available in certain areas, and store food within their tunnel systems [72]. When seeds are scarce in spring and early summer, wood mice would consume arthropods and if arthropods lacked abundance then they eat buds/ young shoots of green plants [73]. A study by Rodgers and Gorman [74] *stated* that Wood Mice diet in set aside land contained a lot less seed or animal material as they consumed 87% plant material, 65% of which was green biomass, this diet was reflected by the food available in the area. Food choice is also dictated by age as younger Wood Mice would eat fewer seeds and a higher variety of food compared to the adults [73].

The dietary behaviour of Yellow Necked mice is very similar to the Wood Mice as they also consume tree seeds, fruits, buds and invertebrates [43,54,70] while also storing within tunnel systems [75]. *A. sylvaticus* and *A. flavicollis,* like all mice, engage in the process of 'refection' in order to fully digest their food. This involves eating soft faeces that have previously passed through their digestive system once in order to allow carbohydrates to be fully digested the second time around [75].

The dietary behaviour of the Bank Vole is found to be almost wholly herbivorous [76], although some invertebrates are consumed [73], taking seeds and forbs [77], fleshy fruits [68] and soft testa seeds when available [73]. Macdonald and Feber [77], states around half of their diet consists of green leaves and woody plants are favoured over herbs [68,73]. In the winter, Bank Vole eat large amounts of dead leaves [68,73] which qualifies them for a place among the decomposers [73]. Young bank voles eat fewer seeds and fruit than adults [73].

Field Voles just like Bank Voles are primarily herbivorous, feeding primarily on the green leaves and stems of grasses [27,68]. Field Voles are also known to gnaw on tree bark in the winter and are known to consume animal prey e.g. Dipteran larvae [27].

All Shrews are insectivorous [68] and notorious for their insatiable appetites as they need to eat every 2-3 hours in order to consume 80-90% of their body weight daily [78], therefore, food availability is a crucial habitat factor affecting shrew abundance and distribution [68]. *Common Shrews* are optimistic feeders that prey on terrestrial invertebrates mainly found in hedgerows; especially beetles, slugs, snails and earthworms [26,79]. The diet of *Pygmy Shrews* is similar with the exception of earthworms. Therefore, *Common Shrew* abundance and distribution will be dependent on earthworm distribution while *Pygmy Shrew* is dependent on the surface- living invertebrate density.

Importance of hedgerows to small mammals:

Hedgerows are crucial and are an often indispensable habitat for mammal species of mammals within arable landscape despite only comprising a small percentage of the UK countryside (Tattersall and McDonald, 2003; Butet et al., [43]). A large amount of British mammals developed and evolved in and around deciduous woodlands [77,80], but over time, many species have now adapted to exist within arable landscapes; through frameworks of field margins and boundary features. Hedgerows are utilised by mammals in many ways, from feeding [70] and refuge whether its shelter or protection from predators [81] to use as ecological corridors for landscape dispersal [82].

It is stated by Boone and Tinklin [83] that the hedgerows vegetation structure is vital in influencing both the occurrence and densities of Wood Mice and Bank Voles. Sites which consisted of higher vegetative cover and food availability were correlated with higher Wood Mice and Bank Vole population densities. Both of these species are important as prey species for other predatory species as previously discussed. In arable landscapes, predator species populations linked with hedgerows e.g. such as Fox (*Vulpes vulpes*), Weasel (*Mustela nivalis*) and Stoat (*Mustela erminea*) form a large amount of the overall predator community [11,83].

Sohler [84] discovered that, in hedgerows around 2-13 years old, small mammal densities which were trapped increased with hedgerow age; however this could also be due to hedge size. The correlation is that where hedgerow margins are left to spout out onto the bordering land, the richness and diversity of small mammal species will increase; this could be down to the fact that wider hedgerows are more effective as ecological corridors [85].This is possibly reflected by the greater numbers of mammals which use hedgerows for foraging and shelter [11,86].

A hedgerow's value as a wildlife habitat is affected strongly by its structural condition. It has been acknowledged that the abundance of Bank Vole [43] and Yellow Necked Mice [54] are negatively associated with low amounts of vegetation cover and increased number of gaps present in a hedgerow [11,86].

AIMS, OBJECTIVES AND NULL HYPOTHESES

From reviewing the literature it is clear that linear boundary features such as hedgerows play an important part in providing habitat connectivity for dispersal, habitat and food source for small mammals. However, composition and structure of these features are known to affect small mammal species abundance and diversity.

Therefore, the aim of this research is to study the effects of two linear features of different composition on small mammal abundance and diversity.

This will be assessed through:

- The use of Longworth Traps along a designated 30 metre linear trap line
- A Pilot study over a month course to see species presence
- A Real study over a month that follows the small mammal trapping protocol [87].

Taking down species identification, weight, sex and giving a specimen a mark code (A-F and combinations of) to show unique vs recurring individuals.

This leads to the following null hypothesis: That there is no difference in small mammal abundance and diversity between the two linear features.

MATERIALS AND METHODS

Site area

Two comparison linear boundary habitats, located on the Writtle College estate in Essex and adjacent to agricultural land,

were used for this research and comprised of a well-developed vegetative established hedgerow and a woody fence feature made up of compiled branches and small trunks of various tree species, both indicated by yellow lines in Appendix I.

The established hedgerow (OS Grid reference TL 66961 06920) (Appendix III) is some 170 metres in length with a width of two metres. Compositionally, this linear habitat consists primarily of a range of native woody species; species including Hawthorn (*Crataegus monogyna*), Blackthorn (*Prunus spinosa*), Field Maple (*Acer campestre*) and a small presence of Crab Apple (*Malus sylvestris*) Elder (*Sambucus nigra)* and Wych Elm (*Ulmus glabra*). The ground layer under the woody species is extremely sparse, however, along the edges of the hedgerow are dense margins of grasses (predominately Soft Brome (*Bromus hordeacues*) and False Oat grass (*Arrhenatherum elatius*) along with the presence of Common nettle (*Urtica diocia*). This hedgerow is located adjacent to two arable fields. The field to the west was utilised for crop harvest **(Plate 1)** whilst the field to the east had a small section (directly adjacent to the hedgerow) dedicated to Sweet Potato (*Ipomoea batatas*) **(Plate 2)** harvest whilst the rest of the entire field was dominated by growth of Perennial Ryegrass (*Lolium perenne*).

Plate 1. Agricultural field on the west of the hedgerow (Authors own picture).

Plate 2. Agricultural field to the east of the hedgerow (Authors own picture).

The Woody fence feature (OS Grid reference TL 66405 06701) (indicated by the yellow line in Appendix II) is only 30 metre in length with a width of 0.5 metre. Compositionally, this linear habitat consists of compiled, tightly compacted, accumulated branches from Silver Birch (*Betula Pendula*), Ash (*Fraxinus excelsior*) and Hornbeam (*Carpinus Betulus*) **(Plate 3)** with scatterings of Bramble (*Rubus fruticose*) across the feature **(Plate 4).** The ground layer was sparse directly underneath the feature, however, along the feature edge were dense margins of Soft Brome (*Bromus hordeacues*), False Oat grass (*Arrhenatherum elatius*) Common nettle (*Urtica diocia*), Bramble (*Rubus fruticose*) and Creeping Thistle (*Cirsium arvense*). This hedgerow is adjacent to woodland (consisting of species such as English Oak (Quercus robur), Hornbeam (Carpinus betulus) and Black Poplar (Populus nigra) to the west and semi-improved grassland to the east.

Plate 3. Wood fence (Authors own picture).

Small mammal surveys

Pilot study (25/9/2015- 12/10/2015): During the Pilot study, 23 Longworth traps **(Figure 1)** were laid (in situ) at each site within the linear feature itself with a distance of 1.5 metres, indicated by a position identification cane, between them along the trap line, the traps were then externally covered with long dry grass to camouflage them and to protect the captured specimens caught from the cold environmental temperatures

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Plate 4. Wood fence with evidence of shrubbery (Authors own picture).

Figure 1. Longworth Trap.

The traps were left open for a four day period per week during this study and were checked twice a day (AM and PM). After the 4 day period, the traps were then closed for three days to reduce the amount of disturbance to the site. However, traps were also forced to be closed when the weather was deemed too severe for the traps to be left open.

The resting chambers of the traps were filled with two main components; dry hay for the purpose of thermoregulation during the cold external temperatures and the food which consisted of porridge oats for the rodents (i.e. Mice and Voles) whilst a small handful of dried mealworms and 10 grams of Blowfly castors were for Shrews; in the off chance they were captured.

During the checking of the traps, every trap whether the door was down or open was opened for animal welfare reasons. The traps were placed, tipped and emptied out into a large polythene bag. If there wasn't a specimen inside then the trap was then refilled and hay and/or food replaced if necessary. However, if there was a specimen inside then the hay in the bag was removed in order for access to handling of the animal.

The animal individual was then noted based on species identification, sex and weight and then given a small fur snip on its flank as an indicator of previously caught; if caught again. Once all these were completed and noted down, the animal was released at the point of capture.

All traps were reset (and recovered with dry grass) in their original spots with changed hay if there was an animal caught within and food topped up if necessary. Changes to the hay are also necessary and vital if it is damp, wet or the presence of blood since wet conditions are known to result in greater risk of mortality of the captured animals due to the damp fur causing inability to thermoregulate properly.

Experimental protocol (23/10/15 – 16/11/2015): During the experimental protocol, position identification canes were put in the 30 metre hedges section with a distance of five metres between them which totalled to seven trapping positions along the linear trap lines. At each position, two Longworth traps were laid down within one metre proximity of the cane. This equalled to 14.

Longworth traps laid at each site initially within the linear feature itself, then the traps were covered externally with long dry grass to camouflage them and to protect the captured specimens caught from the cold environmental temperatures **(Plate 5).**

Plate 5. Bank Vole being handled for sexing (Authors Own).

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The traps were open for a 4 day period and during this period; were checked twice a day (AM and PM). After the 4 day period, the traps were closed for 3 days to reduce the amount of disturbance to the site. However, traps were also closed when the weather was deemed was deemed too severe for the traps to be left open.

The resting chambers of the traps were filled with two main components; dry hay for the purpose of thermoregulation during the cold external temperatures and the food which consisted of Porridge oats for the rodents (i.e. Mice and Voles) whilst a small handful of dried mealworms and 10 grams of Blowfly castors were for Shrews; in the off chance they were captured.

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The animal was then noted based on species identification, sex and weight and then given a small fur snip on its body corresponding to the fur marking code **(Figure 2)** and the marking code was recorded (coded A-F) and variation of letters were made if animal went over F as an indicator of previously caught; if caught again. Once all these were completed and noted down, the animal was released at the point of capture. When 50-60% of the traps per point were occupied, one further trap was laid within one metre of the cane at that particular point.

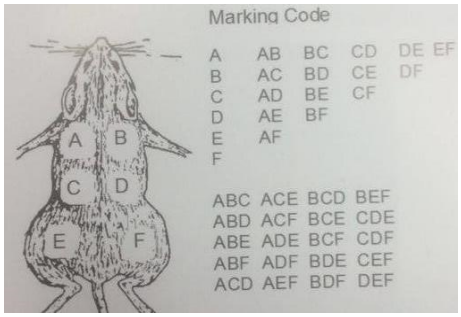

Figure 2. Fur marking code (Gurnell and Flowerdew, 2006).

All traps were reset (and recovered with dry grass) in their original spots with changed hay if there was an animal caught within and food topped up if necessary. Changes to the hay are also necessary and vital if it is damp, wet or the presence of blood since wet conditions are known to result in greater risk of mortality of the captured animals due to the damp fur causing inability to thermoregulate properly.

Ethics

The experimental procedure was carried out in accordance with the requirement of the license to trap shrews issued by Natural England and was approved by the Writtle College ethics committee.

Statistical analysis

All the data collected was analysed in Microsoft Excel and Past statistics software.

All the data of the caught specimens were inputted into a Microsoft excel spreadsheet and species data noted were separated by the site in which they were caught in. The percentage make up of species caught was calculated to see the most abundant mammal species per site and overall.

The added total of unique individuals from all species was used to calculate both the Simpson and Shannon diversity indexes and unique species homogeneity was calculated by the use of Chi-squared goodness of fit statistical test, to discover the difference in diversity between the two sites.

The data of all the species per site was then separated into species weight and sex and then the data was analysed by using Mann-Whitney U test to compare the data of these two categories.

The trapping night index (TNI) was used to see to average nightly catch per species at each site to give an indication of where is the most abundant site with reference to species caught.

Finally, a dot density linear map was constructed based on position captures to see where the most popular areas of the sites were and the species caught. This could then utilised as an indication of species ecology due to specific hedgerow characteristic influence.

In all analyses, statistical significance was taken at $P<0.05$.

RESULTS

Pilot results

The results of the pilot study show that Wood Mice dominated the overall trapping captures; with a combined total of 67%

made up from both of the sites; making up 61% of the total caught in the woody fence feature and 75% in established hedgerow . Bank Vole was the second most abundant small mammal species with a 28% overall total of both sites; made up 33% caught in the woody fence feature and 19% in established hedgerow. However, Yellow Necked Mice and Field Vole were very sparse and each only made up less than five percent of the total catch of both sites combined.

There was no significant difference found in the mammal species abundance and diversity (based on the number of unique individuals) between the two sites during the pilot study (P = 0.474). Overall, the woody fence feature site had little over one and a half times the number of unique individuals compared to the established hedgerow; with over double the amount of unique Bank Vole **(Table 1).**

Experimental protocol results

Over the duration of the research following the experimental protocol, three species of small mammals were recorded (Wood Mice, Bank Vole and Yellow Necked Mice) **(Table 2).**

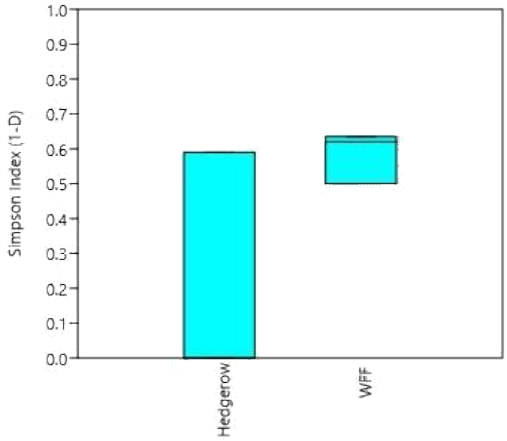

Figure 3. Simpson Diversity Index of both sites.

Table 1. Species caught and amount per site.

Species	Woody fence feature	Established Hedgerow	Total
Apodemus sylvaticus	35	28	63
Myodes glareous	19	8	26
Apodemus flavicollis	1	1	2
Microtus agrestis	2	1	3
Total	57	37	94

Table 2. Trap night index of pilot month.

Site	Species	Trap-nights	No.of individuals	Total catch	TNI (individuals)	TNI (total catch)
Established	*Apodemus sylvaticus*	13	28	44	2.154	3.38
	Clethrionomys glareolus	13	8	11	0.636	0.85
Hedgerow	*Apodemus flavicollis*	13	1	1	0.077	0.077
	Microtus agrestis	13	1	2	0.077	0.154
	All Species		**37**	**58**	**2.908**	**4.461**
Woody Fence feature	*Apodemus sylvaticus*	13	35	52	2.69	4
	Clethrionomys glareolus	13	18	25	1.38	1.92
	Apodemus flavicollis	13	1	1	0.077	0.077
	Microtus agrestis	13	2	2	0.154	0.154
	All Species		**56**	**80**	**2.91**	**3.377**
Both Sites	**All Species**		**86**	**138**	**5.818**	**18.45**

Small mammal species abundance and diversity found at the wood fence feature habitat was found to be statistically significant (P=0.0264) compared to the hedgerow since all three species caught were trapped at the wood fence feature, compared to only Wood Mice being captured at the hedgerow (**Tables 3 and 4).** Collectively, the presence of Wood Mice was omnipresent, caught during all trapping sessions and a maximum of 13 and 23 unique individuals recorded in the hedgerow and the wood fence feature, respectively. Unique Wood Mice individuals made up 64.8% of the wood features total catch and the whole 100% of the hedgerows during this research duration. Like Wood Mice, Bank Vole was also caught during all sessions at the wood fence feature (making up little over 24% of the catch) but was absent at the hedgerow. Yellow Necked Mice, just like the

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Bank Vole was likewise absent from the hedgerow, but this species an occasional catch at the wood fence feature site (making up little over 10% of the total catch).

Table 3. Overall species individuals caught and amount per site.

Species	Woody fence Feature	Established	Total
Apodemus sylvaticus	23	14	37
Myodes glareous	10	0	10
Apodemus flavicollis	4	0	4
Total	37	13	50

Table 4. Unique species individuals caught per site per month.

Species	Established Hedgerow		Woody Fence Feature	
	October	November	October	November
Wood Mouse	8	6	10	13
Bank Vole	0	0	3	7
Yellow - Necked	0	0	0	4

Overall small mammal species diversity was found to be higher at the wood fence compared to the hedgerow. The calculated Simpson diversity index (1-D) for the small mammal community at the wood fence ranged from 0.5 to 0.635 **(Figure 3)**; the Shannon diversity index (H) ranged from 0.951 to 1.05 **(Figure 4).** The calculated Simpson diversity index (1-D) for the small mammal community at the hedgerow was 0.59 **(Figure 3)**; the Shannon diversity index (H) was 0.984 **(Figure 4).**

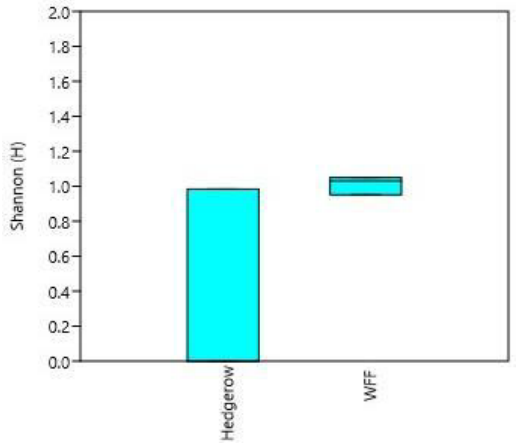

Figure 4. Shannon Diversity Index of both sites.

Trap Night Index (TNI)

The results from the TNI shows that on average per night, catch of unique individuals was nearly three times and catch of all individuals (including recurring) was little over three times higher in the wood fence feature than in the established hedgerow **(Table 5).**

Table 5. Trap night index of real month.

Site	Species	Trap- nights	No. of individuals	Total catch	TNI(individuals)	TNI(total catch)
	Apodemus sylvaticus	10	13	20	1.3	2
Established	*Clethrionomys glareolus*	10	0	0	0	0
Hedgerow	*Apodemus flavicollis*	10	0	0	0	0
	All Species		**13**	**20**	**1.3**	**2**
Woody	*Apodemus sylvaticus*	10	23	27	2.3	2.7
Fence	*Clethrionomys glareolus*	10	10	13	1	1.3
feature	*Apodemus flavicollis*	10	4	4	0.4	0.4
	All Species		**14**	**21**	**3.7**	**4.4**
Both Sites	**All Species**		**27**	**41**	**5**	**6.4**

The median weights for Wood Mice (Male and Females collectively) ranged from 16g to 18.5g in the established hedgerow and 16g to 18g in the wood fence feature. These ranges were not statistically significant (P=0.4). The change of the weights of Wood Mice from October to November was also not statistically significant in both sites (P= 0.24 in the hedgerow and P= 0.69 in the woody fence feature) **(Table 6).**

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Table 6. Weight and sex ratio for wood mice in both sites.

			Established Hedgerow				Woody Fence Feature	
Year	**Month**	**Sex**	**Median (g)**	**Range (g)**	**Sex ratio (male: female)**	**Median (g)**	**Range (g)**	**Sex ratio(male: female)**
2015	Oct	Male	18.0 (6)	17 - 19	03:01	17.0 (5)	16 - 18	01:01
		Female	18.5 (2)	17 - 20		18.0 (5)	14 - 31	
	Nov	Male	16.0 (6)	14 - 27	06:01	16.0 (12)	Sep-20	06:01
		Female	N/A	N/A		17.5 (2)	15 - 20	

Unique Male Wood Mice were more prominent in this research overall compared to females. Results from October showed that three times as many males were caught compared to females in the hedgerow while at the wood fence; the sex ratio was even. Nevertheless, both sites saw a Wood Mouse male to female ratio of six in November, however, this ratio in the hedgerow was based purely on numbers of males since no females were caught while in the wood fence the sex ratio was based on the difference between males and females.

Wood Mice in the established hedgerow appeared at all but two points and the trapping density of Wood Mice was found to be more concentrated towards points six and seven in the hedgerow while at the wood fence, they were caught at every point along the trap line; with emphasis at point two. Bank Vole trapping density was also shown to be dispersed along the trap line, with a high capture concentrated at point five. Yellow-Necked Mice, like Bank Vole and Wood Mice, was also shown to be dispersed along the wood feature trap line, however, data shows no clear concentration was found. **(Figures 5 and 6).**

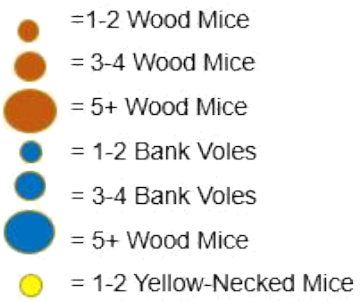

Figure 5. Dot Density Map of Species caught per point. Where H refers to the established hedgerow and WFF refers to the woody fence feature.

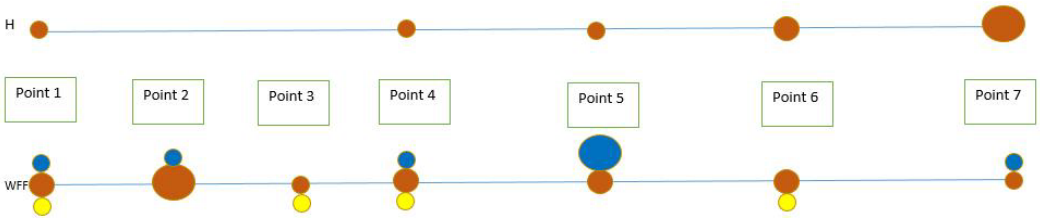

Figure 6. Legend for the Dot Density map.

Only the results from the experimental protocol duration were used in the discussion.

DISCUSSION

Effects of linear boundary characteristics on small mammal species

Overall in this research, three small mammal species Wood Mice, Bank Vole and Yellow Necked Mice were trapped during this study. These three species are all common and widely distributed around Essex and the rest of the UK [26,45], with the exception of the Yellow Necked Mouse as their distribution is more limited; being restricted to Southern England and Wales [26,88].

Wood Mice, Bank Vole and Yellow Necked Mice in agricultural landscapes are regularly found in linear boundary habitats [54,89-92].

Wood Mice association with agricultural habitats is well documented [54] and the trapping of Wood mice during this study in both of the different characteristic linear habitat boundaries are associated with this species recognised ecology as an extremely active and adaptable [54], opportunistic habitat generalist species [93,94].

Wood Mice are known to be not particularly influenced by characteristics of linear habitats but nevertheless tend to favour habitats with high amounts of canopy cover and little ground cover [54,83,84]; Moro and Gadal, Studies on Wood Mice population density by Kotzageorgis and Mason [54] indicated that this species dependency on the resources provided by hedgerows, increases throughout the year, towards autumn and winter in arable landscapes.

In this research, from the results of the data, Wood Mice dispersal was found to be generally spread along the linear boundaries with some concentrated points, points six and seven in the hedgerow and point two in the wood fence **(Figure 7)**, These higher species activity at these points on the linear feature could be explained by the provision of food at these certain points. Points six and seven in the hedgerow has provisions of fallen apples and Blackthorn sloes while point two in the wood fence is surrounded by blackberries from the low-lying Bramble. These concentration observations were similar to that found by Weisel and Brandl [95]. Weisel and Brandl [95] found higher densities of small mammal species in some areas compared to others due to better quality and quantities of food resources, which is in keeping with the results found by Poulton [96] who found that Wood Mice capture rates were strongly associated with hedgerow berry abundance.

A 5.75 ratio of Wood Mice to Yellow Necked Mice was discovered in this study, similar to results found in other Essex studies [54]. This is due to the sparser Yellow Necked Mice's tree seed dependency, thus requiring a longer linear line home range in order to cover many possible sources of food [54].

Yellow Necked mouse was only caught in the wood fence feature in the experimental protocol study, despite being caught in the hedgerow during the pilot study which is consistent with their known ecology as a more deciduous woodland (arboreal) residing species [54,97], with some presence in hedgerows [23]. Linear boundaries in close proximity with woodland in the autumn have been acknowledged for having a positive influence on Yellow necked mice populations [54]. The absence of this species from the hedgerow during the experimental protocol could be explained by this species key requirement for good hedgerow condition, the hedgerow general foliage cover was declining due to the effects of autumn on deciduous species phenology which meant gaps in the hedgerow were increasing and becoming more apparent and this factor, with the exception to Sohler [84] who found that Yellow Necked preferred areas of little and no foliage, this species and number of gaps present are negatively associated since the habitat temporarily loses the inability to support stable populations [11,54,98].

Like the Yellow Necked Mouse, Bank Vole was also caught only in the wood fence during the experimental protocol despite also being caught in the hedgerow during the pilot study. Bank Voles are habitat generalists, however they hold a strong fondness for ground vegetation cover [54,68] and seem to be restricted to linear boundary habitats primarily in agricultural landscapes [54,89,99,100] .

It is acknowledged that linear boundary structural condition including higher levels of vegetative cover and food availability is correlated with higher occurrences and densities of Bank Vole [43,83] along with many other small mammal species. However similarly to the Yellow Necked Mice, Bank Vole are also negatively associated with linear boundary "gappiness" [54]. The growing absence of vegetative cover and increasing number of gaps due to deciduous tree phenology may, therefore, explain the absence of this species from the hedgerow. Bank Voles in the autumn were found to be more abundant in linear features in close proximity to woodlands [20] which could further explain their presence at the wood feature and absence from the hedgerow.

Bank Vole dispersal was found to be generally spread along the linear boundaries with a concentrated capture rate at point five. Point five was in very dense low- lying vegetative cover with some presence of Bramble shrubbery which would explain the high capture rate as it fitted with their ecology and habitat preferences. This observation is similar to the study on Vole distribution within linear boundaries in association with seed and berry abundance [96].

However this observation was also similar to that found by Weisel and Brandl [95]. Weisel and Brandl [95] found higher densities of small mammal species in some areas compared to others due to better food resources.

The sex ratio of all three species captured showed a male bias which is similar to many previous studies [54,76,92,93]. This ratio is related to changes in the social and spatial behaviour of the males and their increased habitat dispersal [93].

Conservation implications

It is shown by the results of this study that compiled woody linear fence features have some characteristics and stature which are beneficial to and have the potential to assist in the conservation of small mammal species. This indicates that strategically put up linear features in different locations are important and should be utilised as a good habitat management practice for the provision of food, shelter and contributor to species dispersal by taking the role as ecological corridors, in addition to management of current established hedgerows to reduce the risk of the potential to convert into "relict" hedgerows and lose their value as a suitable wildlife habitat; affecting their use and effectiveness in the conservation of farmland biodiversity.

Research limitations

Throughout this study, a few external and environmental research limitations occurred which may have affected data and results. Due to wet weather or weather deemed too extreme for trapping, the traps had to be closed for reasons previously explained; therefore, some sampling days were missed out, affecting further potential findings and outcomes.

After the pilot study, agricultural practices occurred for a few days in both of the fields adjacent the hedgerow. This would have created a large amount of anthropogenic disturbance to the site and consequently cause a reduction in mammal abundance thus having adverse effects on the data from the live trapping at the site.

The duration of this study was shortened due to limit of time possession of the borrowed traps was available. A longer duration would have created more opportunities to capture additional small mammal species and receive further data.

Limitations also derived from the Longworth traps, with issues including limited numbers and the general trap mechanic problems. With the amount of traps available, only a study on two varying linear features was carried out effectively and efficiently. If there were more traps accessible for this research then it would have provided the opportunity to survey further linear features comprising of different characteristics and opportunities of longer linear trap lines.

Throughout the duration of the research, some traps had issues with their internal mechanisms which led to a small number of capture "false alarms" due to their doors being closed with no animal inside. Door closures will with a doubt reduce the opportunities for specimen capture and affect the amount of data collected.

Recommendations for further research

There are several recommendations for further research in this area of study. The use of more traps would be suggested and beneficial because it would allow the opportunity for longer linear trap lines as well as more chances to survey more different linear features of diverse features and achieve more data.

A similar study could be replicated, with or with not longer survey duration, in linear boundary features in a similar landscape in a different geographical location to see if species abundance and diversity data is related. Similar studies can also be reproduced in linear boundary features in a dissimilar landscape.

This study can also be replicated at different seasons of the year since characteristics of linear boundaries alter throughout the year such as floral growth and declines and food supplies which influence small mammal species abundance and diversity.

CONCLUSION

In conclusion, the difference in abundance and diversity of small mammal species between both of the linear boundaries was statistically significant (P=0.0264). Such associations between certain small mammal species and particular linear boundary characteristics were exhibited. The decreasing amounts of vegetation in the hedgerow which correlated with increasing volumes of gaps was negatively associated with Bank Vole and Yellow Necked mice abundance. Wood Mice appeared in both linear boundaries but was more concentrated in areas with large provisions of food. Bank Vole appeared across in the wood fence feature only but their trapping was concentrated around low dense shrubbery with and without provisions of food. Yellow Necked mice, just like the Bank Vole appeared across the wood fence feature only with no obvious trapping concentration. Therefore this study reveals the overall importance of linear boundary features with a well-developed vegetation structure on small mammal communities in agricultural landscapes. Such differences in small mammal abundance and diversity is related to particular characteristics of the boundary habitats.

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