LANDSCAPE CHANGE ON SITES in the PARTRIDGE PROJECT

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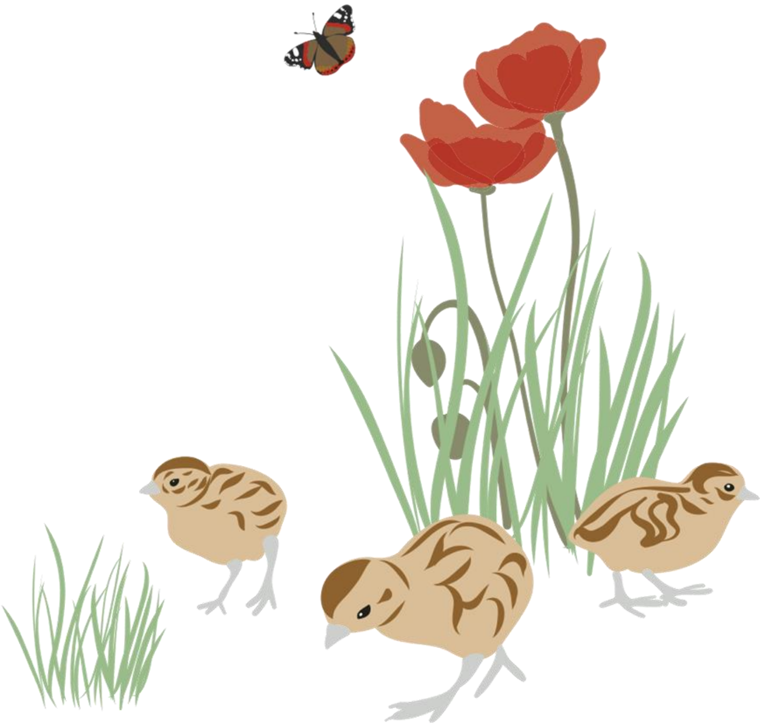
Preface

PARTRIDGE was a demonstration project with 13 European partners, 50% co-funded by the Interreg North Sea Region Programme, running from mid-2016 to mid-2023. The project worked across demonstration areas in five participating countries (two sites in each country: Belgium - Flanders, England, Germany - Lower Saxony, the Netherlands, and Scotland). Partners from Denmark joined the project in 2019, although there were no project sites in this country. For more information about the project please visit northsearegion.eu/partridge.

At each demonstration site PARTRIDGE partners provided advice and support to local farmers, encouraging, and enabling them to establish and manage habitat measures designed to restore numbers of grey partridges and other farmland flora and fauna. Each of these demonstration sites was paired with a nearby reference site, which was not specially managed to restore biodiversity but is instead indicative of typical farmland in that region. One of the goals of the project was to establish high-quality agri-environment habitat on at least 7% of each demonstration site's farmed areas. Habitat measures were selected based on their ability to aid in the conservation of grey partridges – a key indicator species of farmland ecosystem health and an umbrella species for farmland biodiversity.



Executive summary

The decline of farmland biodiversity across Europe necessitates urgent action and innovative solutions to prevent further loss and recover wildlife populations. Between mid-2016 and mid-2023 the Interreg PARTRIDGE project worked to improve ten 500-hectare working farmland demonstration sites in five participating countries (two sites in each country: Belgium - Flanders, England, Germany - Lower Saxony, the Netherlands, and Scotland). Each demonstration site was paired with a nearby reference site for comparison.

At these project sites we established new wildlife-benefitting habitat (predominantly PARTRIDGE wild-bird mixes) and improved existing beneficial habitat to ensure that 7% of the farmed area of each demonstration site provided both summer nesting and brood-rearing benefits, and overwinter food and shelter. Additionally, we undertook supplementary winter feeding to ensure wildlife had sufficient overwinter resources.

Our key bioindicator was the grey partridge (*Perdix perdix*) an umbrella species in arable habitats. By improving conditions for the grey partridge we will also benefit many other farmland species. Habitat mapping was undertaken to determine not only our progress towards establishing 7% habitat at each demonstration site, but also the effect of this habitat establishment upon the landscape.

Our key results show that:

- We far exceeded the target of 7% beneficial habitat for grey partridge by the end of the project, achieving a maximal coverage of 13.7% in 2021. All demonstration sites were above the 7% target in 2022 apart from our two Scottish sites due to a variety of complications.
- The beneficial habitat at our demonstration sites was more diverse than that at our reference sites.
- Beneficial habitat was not evenly spread across our demonstration sites, but instead clustered together in compact arrangements. Ensuring a more even arrangement of habitat may have resulted in a greater recovery of wildlife at our demonstration sites.
- The quality of beneficial habitat was significantly greater at our demonstration sites, with the amount of core habitat (i.e., habitat with a significantly reduced predation risk) up to an order of magnitude greater than at our reference sites by the end of the project.

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Introduction

Farmland occupies a considerable proportion of Europe. Roughly 38% of the terrestrial area of the European Union (EU) was managed for agriculture in 2020 (Eurostat, 2022), with the result that the farmland biodiversity crisis affects a large part of European landscapes. The Common Agricultural Policy (CAP), and now in the United Kingdom the Environmental Land Management Scheme (ELMS) and the Agri-Environment Climate Scheme (AECS), aims to reverse the decline of farmland biodiversity across arable landscapes through Agri-Environment (AE) Schemes . By most measures the CAP has failed to meet the EU's biodiversity 2020 targets on farmland (European Court of Auditors, 2020), with no indication that it will meet the 2030 targets.

It was against this background that PARTRIDGE set out to demonstrate how biodiversity can be restored across an agricultural landscape at each of its ten 500-hectare demonstration sites across the North Sea Region, show-casing novel management solutions which can then be applied across the entire EU. Our approach to successful biodiversity restoration was based on the following statement: 'if you do what is right for the grey partridge, you do what is right for farmland biodiversity'. Using the grey partridge *(Perdix perdix)* as an umbrella species for farmland biodiversity generally, together with its status as an indicator for farmland ecosystem health (Potts, 2012; Sotherton, Aebischer & Ewald, 2014), we tailored our management plans to the species' well-researched and understood ecological requirements. We summarised these in our publication 'Farming with Nature – promoting biodiversity across Europe through partridge conservation' (Brewin, Buner & Ewald, 2020). A key requirement for grey partridge recovery is sufficient and adequate wildlife-friendly habitat provision. The minimum level required is thought to have to cover at least 7% of a farmed area (Winspear *et al.,* 2010; Gottschalk & Beeke, 2014), ideally 10% (Sharps *et al.,* 2023) which we aimed to establish at all our demonstration sites.

The primary habitat we sought to promote and establish at our demonstration sites were species-diverse wild-bird mixes (right), often using our bespoke PARTRIDGE seed mix, planted in blocks which provides a wide range of benefits for grey partridge and other wildlife year-round – delivering nesting, brood-rearing, and overwinter cover (Brewin, Buner & Ewald, 2020).

An example of our primary habitat measure, a wild-bird mix, established at the Diemarden demonstration site. This measure benefits grey partridge and numerous other species throughout the entire year © Lisa Dumpe

Support and advice from PARTRIDGE partners, using the grey partridge as a key motivator for stakeholder engagement, encouraged farmers and hunters to manage their farms in a more wildlife-friendly way, providing new, beneficial habitat patches. Each demonstration site was paired with a reference site within a range of 2 - 16 km, which served as an example of 'typical' management for the local farmed landscape. We measured habitat changes that took place in both the demonstration sites and their paired reference site, including changes to cropped areas, semi-natural habitats, and any beneficial habitats. This report summarises these changes, determining the effects they have had on the composition, complexity, and configuration of the landscape.

We expected that the addition of beneficial wildlife habitat to the demonstration areas would result in a more complex landscape, capable of hosting more biodiversity (Estrada-Carmona *et al.*, 2022). For the purposes of this report, we have divided landscape complexity into three separate aspects: composition, heterogeneity, and configuration (Estrada-Carmona *et al.*, 2022). **Composition** is the simplest and best understood of the three, as it is simply the proportion of different habitats present in the landscape. **Heterogeneity** measures the diversity of habitats, whilst **configuration** measures the shape and spatial arrangement of habitats. We analysed the effect of the changes undertaken by farmers and land managers on the sites to alter each of these aspects of complexity, using a range of metrics for each of the three aspects.

Materials and methods

Mapping protocol

Habitat information was digitised by the partner organisation responsible for the management of each site. As the project spanned multiple organisations, across multiple countries, we ensured that mapped data was captured in a consistent manner using a shared habitat mapping protocol (see 'Appendix: Mapping Protocol'). Within the mapping protocol we specified that, for each project site, habitat data was to be recorded twice a year from 2017 to 2022 – with one set of maps capturing summer habitat (the period of May to August), and another map capturing winter habitat (October to January). This habitat information was digitised as polygonal vector data, obtained through cropping maps and in-situ ground truthing. All habitat features with a minimum area of 100 m^2, and a minimum width of 1.5 m, were captured in this manner.

Information on the specific type of habitat present was recorded using a set of mutually agreed-upon codes, with these codes stored within the mapping protocol. Additional codes were created by the mapping coordinators on request from individual partners. In total, 168 unique codes were designated for use within the project. Further information on the geometry and management of each habitat patch was to be included in the attributes recorded for each polygon. This included rough estimates of width and height (for those features where this information was important, e.g., semi-natural features such as hedgerows, lines of trees). In the case of grass-dominated features we recorded the management of the grass, how the grassland was established, and whether it was considered rotational (part of an arable crop rotation and less than five years since established) or permanent (either long-term leys or more permanent, semi-natural grasslands). Partners also recorded how non-crop habitats such as wild-bird mixes were funded (e.g., through Agri-Environmental Schemes – AE schemes, through PARTRIDGE-provided funding, or whether the habitats were established by the landowner without external funding). There was also a remarks column for additional information or comments.

All maps were validated by the project's mapping coordinator who ensured that submitted maps conformed to the mapping protocol, recorded accurate habitat information, and were free from topographic errors. These validations and any further manipulation were carried out in ArcGIS Pro version 2.9.5 (Esri, Inc., 2021).

Habitat definitions

For the purposes of analysis and the ease of referring to several unique habitats at once, we classified similar habitats into groups. These groups, and the habitats which comprise them, are detailed below.

Crop habitat

All our project sites were in mixed arable landscapes, with the result that the majority of each area was given over to crops – including both arable crops and grassland. Our mapping recorded the species of crop planted. For cereal crops, information was also collected on the timing of sowing, and for grass-crops an effort was made to determine the means of establishment (direct-sown versus under-sown), and the length of time a grass crop had been established (less than or greater than 5-years old).

An example of crop habitat at the Burghsluis demonstration site – spring sown wheat surrounded by Patrijzenrand AE schemes habitat. © Suzanne van de Straat

For several of the following metrics analysed we needed to consider the cropped areas of the landscape separately from other landscape features. Thus, we considered the habitats from the PARTRIDGE Mapping Protocol referred to as 'crop habitat' or 'crops' to be any habitat feature utilising any of the following habitat codes: *1.11.X* (winter stubbles), *1.12.X* (extended overwintered stubbles), *2.X* (anything under the 'Crops' heading), and *3.X* (perennial herbaceous crops').

Agri-environment (AE) scheme habitat

A beetle bank established at the Ramskapelle demonstration site. Our project directly lead to beetle banks being included in AE schemes for the Netherlands and also established throughout Belgium. © Willem Van Colen

All our demonstration sites contained one or more agri-environment options, either pre-existing or established during the project. In some cases, the habitats were introduced outside of an agri-environment scheme, and so our mapping recorded how each of these habitats were funded (see 'Mapping Protocol' above) to delineate between AE schemes options and other habitat.

AE scheme habitats on our sites included: *1.6* (beetle banks; pictured left), *1.7.X* (headlands and unharvested crops), *1.8.X* (grass margins and meadows), *1.9.X* (wild-bird cover), *1.10.X* (pollen & nectar mixes), *1.11.X* and *1.12.X* (winter stubbles and extended overwintered stubbles), and a variety of additional habitats.

Semi-natural habitat

Semi-natural habitats are areas of the landscape that are not actively farmed, retaining vegetation that is associated with 'natural' ecosystems. In the arable landscape these are represented by woodlands, hedgerows, and other herbaceous boundaries. The explicit codes from the PARTRIDGE Mapping Protocol included were all habitats under the 'Semi-natural habitat (SNH)' heading within the mapping protocol, including all those codes beginning: with *1.1.X* (woodlands), *1.2.X* (hedges), *1.3.X* (herbaceous areal elements), and *1.4.X* (herbaceous linear elements).

Urban areas

As our project sites are all in mixed arable landscapes, the areas mapped do not include cities or large towns. However, there were some rural urban areas, made up of houses, barnyards, and transport networks, which were included in our habitat maps. The explicit codes from the PARTRIDGE Mapping Protocol that identified urban areas included any digitised habitat feature using a habitat code beginning: with *5.X* (Urban areas), in addition to *7.1* (road paved), *7.2* (farmland track, unpaved), 7.2.1 (farmland track (dirt/green)), *7.3* (footpath), *7.4* (railway) and *7.6* (barnyard).

Beneficial habitat

We assessed all habitats within the mapping protocol for the benefits they provide to grey partridge and other farmland ground-nesting birds, using the expert knowledge of our partners. We identified which habitats provided *nesting* or *brood-rearing* benefits using the maps representing habitats during the summer months. Nesting habitats allowed for the concealment of grey partridge nests, whilst brood-rearing habitat provided invertebrates, which grey partridge chicks, and the chicks of other farmland birds, need in the first weeks of life. To be considered as brood-rearing habitat, the vegetation in habitats needed to have an open structure that allowed for grey partridge chicks to easily forage in it. We ranked beneficial habitats: those that provided moderate benefit were scored as *good quality* and habitats that provided excellent benefits were deemed *high quality*. Habitats that did not provide any benefits were scored as being *not beneficial*.

In addition, our experts scored the various habitat types present in our maps in the winter according to their ability to provide overwinter cover and food resources for grey partridges at this time of year. This was assessed to four levels, *escape cover*, *forage cover*, *escape and forage cover*, and *not beneficial*. Habitats which were identified as providing any of the three categories of benefit were classified as beneficial habitat.

All three of these categories of beneficial habitat (*nesting*, *brood-rearing,* and *overwinter cover*) included a wide range of habitats, including those from the 'AE scheme' and 'semi-natural habitat' categories. The full details of our scoring criteria are available in the appendix (see 'Appendix: Scoring Criteria').

These benefit-providing habitats are referred to as 'beneficial' or 'wildlife-friendly' throughout this report.

BEETLE BANK

SUPPLEMENTARY OVERWINTER FOOD

CONSERVATION HEADLANDS

PERMANENT WILDFLOWER COVER

FLORISTICALLY ENHANCED GRASS MARGINS

UNHARVESTED CEREALS

CULTIVATED UNCROPPED MARGINS FOR RARE ARABLE FLORA

ROTATIONAL WILD BIRD COVER

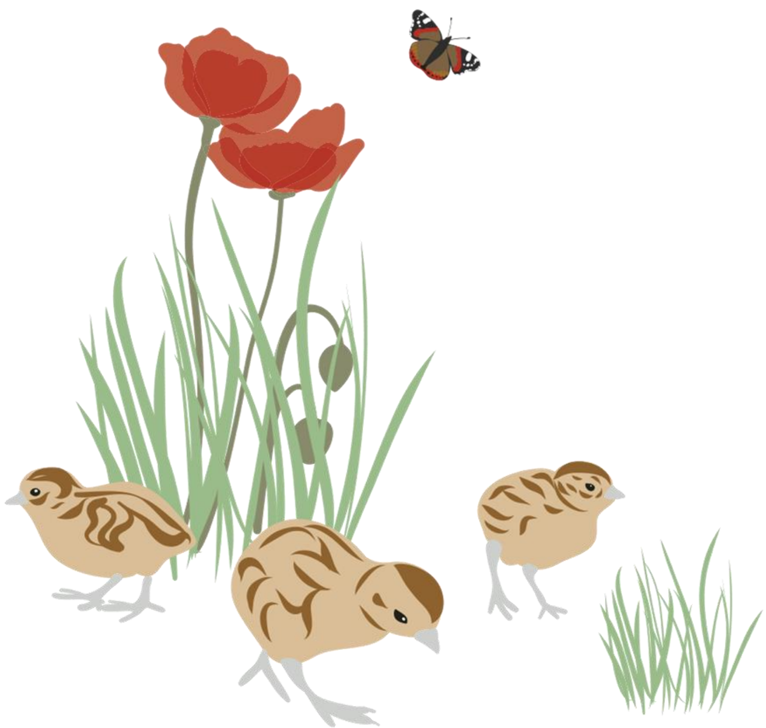
STUBBLES WITH COVER CROPS

Landscape metric calculation

We transformed the mapped vector habitat data into raster layers with a cell size of 1 m^2 (i.e., the landscape was converted into a series of 1 x 1 metre squares). We used this process to prepare raster layers showing the presence of all benefit-providing habitat, crop habitat and semi-natural habitat, in addition to raster layers showing these categories but delineated into unique habitat types, for example benefit providing nesting habitat, brood-rearing habitat, etc.

Whilst our project partners undoubtedly each had different approaches to the digitization of habitat features within their digital maps (for example, recording a network of hedges as one large or several small polygons), converting these to raster data mitigated some of these individual differences and allowed for better comparison between project sites.

These raster layers were used to calculate most of the metrics used to compare changes in landscape between the demonstration and reference areas. Metrics were calculated using version 1.5.5 of the *'landscapemetrics'* package (Hesselbarth *et al.*, 2019) in R version 4.2.0 (R Core Team, 2022). The exceptions to this are any metrics designated with the term of 'polygon size' where metrics were calculated manually using vector data from the original digitised maps in ArcGIS Pro version 2.9.5 (Esri, Inc., 2021).



Analysis metrics

Overview

Table 1. Landscape metrics used in this analysis to examine and quantify the changes in the landscapes of PARTRIDGE sites over the course of the project. A summary of the effects on the ecology of farmland flora and fauna measured by these metrics, together with relevant scientific papers, are presented below.

Landscape metric	Ecological effect	Citation
	Composition	
Broad habitat composition Beneficial habitat composition	The composition of natural and productive arable features affects both the spatial and temporal variation in diversity of bird species.	Santana *et al*., 2017
Non-crop area (%)	Greater proportions of natural or wildlife-benefitting habitat in a landscape benefit biodiversity.	Oppermann, 2012
Beneficial habitat (%) for farmland birds	A greater number of bird-friendly habitats results in greater breeding densities[1] and population growth rates for farmland birds[2].	[1]Aebischer and Ewald 2004; [2]Sharps et al., 2023
Beneficial habitat (%) for hare	Food and cover-providing habitats provided year-round improves reproductive and survival rates of hare.	Smith, Vaughan Jennings & Harris, 2005
	Heterogeneity	
Diversity (*i.e.*, richness, Simpson's, and Shannon's diversity) of beneficial habitat	Increasing habitat heterogeneity within fields may benefit hare populations[1] and increase the richness [2] and abundance[3] of farmland birds.	[1]Smith *et al.*, 2004; [2] McMahon, Purvis and Whelan, 2008; [3]Smith *et al.*, 2010
Diversity (*i.e.*, richness and Simpson's diversity) of crop habitat	Crop diversity is positively related to increased diversity and abundance of invertebrate species.	Aguilera *et al*., 2020
Diversity (*i.e.*, richness and Simpson's diversity) of semi-natural habitat	Semi-natural habitat diversity in arable landscapes positively related to diversity of several invertebrate families.	Hendrickx *et al.*, 2007
	Configuration	
Aggregation index Clumpiness index Normalised landscape shape index Euclidean nearest neighbour distance	Aggregation of habitat patches can increase individual fitness and population growth[1][2] , and diversity of arable bird species[3].	[1]Kanarek *et al.*, 2013; [2]Wozna *et al.*, 2017; [3]Line, 2021
Edge density	More habitat edge positively correlated with the diversity of farmland bird species[1], and abundance of pollinators and natural enemies[2].	[1]Sanderson *et al., 2009*; [2]Martin *et al.*, 2019
Mean contiguity index	Provides information on patch boundary configuration and therefore patch shape (see 'Mean shape index').	LaGro, 1991
Mean field size	Smaller field sizes are correlated to increased diversity of invertebrates, birds, and hares.	Šálek *et al.*, 2018
Mean semi-natural habitat patch size	Increased area of semi-natural patches in agricultural landscapes size is positively correlated to diversity of bird species.	Müller *et al.*, 2020
Mean beneficial habitat patch size	Proximity to habitat edge results in greater likelihood of nest predation for ground-nesting birds.	Morris and Gilroy, 2008
Mean shape index Mean perimeter-area ratio Mean fractal dimension index	Increased shape complexity has minor positive effects on richness and abundance of arable birds[1] and will indirectly impact the density of habitat edge in the landscape (see 'Edge density' above).	[1]Cerezo, Conde & Poggio, 2011
Core area index and percentage of landscape	Predation of hare[2] and ground-nesting birds[1][2] is less likely in habitat cores.	[1]Gottschalk and Beeke, 2014; [2]Hummel *et al.*, 2017

Composition

Broad habitat composition

We compared the proportion of our project sites covered by different broad categories of habitat – namely arable crops, grassland, agri-environment measures, semi-natural habitat, and other habitats- anything which did not fit into these categories. Whilst not a measure of landscape quality, it does provide contextual information on the composition of the landscapes at each of our sites.

Beneficial habitat composition

We also compared the proportion of beneficial habitat at our project sites occupied by different categories of habitat – primarily beetle banks, overwintered stubbles, grass margins, headlands & vogelacker, pollen & nectar mixes, beneficial semi-natural habitat, and wild-bird mixes. These different habitats provide different benefits for our target species (Thomas, Goulson, and Holland, 2001; Ewald *et al.,* 2010; Brewin, Buner, and Ewald, 2020).

Non-crop area (%)

We compared the proportion of our project sites occupied by beneficial habitats and other semi-natural habitats. This excluded crops not included in beneficial habitats and urban habitats. For each unique site-season-year map, we summed the areas of these habitats and divided this figure by the respective site's total area to create a proportion, with separate calculations for summer and winter. We calculated the corresponding value for each of our reference sites. A greater proportion of the site occupied by non-crop habitat denotes a more complex landscape, with a threshold of 20% proposed as a measure to delineate between 'simple' and 'complex' landscapes (Tscharntke, Batáry, and Dormann, 2011; Garibaldi *et al*., 2021).

Beneficial habitat (%)

One of the core aims of PARTRIDGE was to ensure that each demonstration site was enhanced with at least 7% of beneficial habitat. We measured the progress of each site towards achieving this target in our summer maps by summing the areas of all habitats that were scored as *good quality* or *high quality* for *nesting* or *brood-rearing* benefit for ground nesting birds (see Appendix 1; 'Scoring criteria'), and *good-quality* or *high-quality* habitat for brown hare (*Lepus europaeus*). We calculated a proportion by dividing the summed areas of these habitats by the total area of each respective site. Likewise, in our winter maps, for each site we summed the areas of those habitats which were scored as providing *forage cover*, *escape cover*, or *escape and forage cover* for ground nesting birds, and *good quality* or *high quality* for hares. We compared these values to the corresponding value for each of our reference sites. This was calculated for both habitats categorized into individual levels of benefit across all seasons (i.e., *good quality, high quality*) and for all summer and winter beneficial habitats individually by season.

Heterogeneity

The heterogeneity of a landscape is a measure of the diversity of habitats within a landscape. In our case, it is used to measure the diversity of different habitats, such as the diversity of different crops, agri-environment options, or beneficial habitats, across our demonstration and reference areas.

Patch richness

For each category of habitat present on our project sites (i.e., crop, semi-natural and beneficial habitat) we calculated a measure of richness for each site-season-year by counting the number of unique habitat codes belonging to that category within each map. Richness simply measures the number of unique patch types present and does not consider the relative abundance or spatial arrangement of these patches.

Simpson's diversity

Simpson's diversity index is a metric that quantifies the probability that two randomly selected cells of habitat belong to the same habitat type (He and Hu, 2005; Aguilera *et al.*, 2020; Jung *et al.*, 2021). For our purposes this would mean the two cells would both use the exact same habitat code. Higher values of Simpson's diversity index indicate a more diverse landscape, with less of a chance that the randomly selected cells have the same habitat.

Simpson's diversity was calculated using the '*lsm_l_sidi*' function in *landscapemetrics* (Hesselbarth *et al.*, 2019) using the following formula below, where P_i is the proportion of classes (or unique habitat types) I, and m is the number of classes:

$$SIDI = 1 - \sum_{i=1}^{m} P_i^2$$

Simpson's diversity varies from 0 to 1, with a value of 1 indicating uniqueness of the selected habitat, which an even proportion of the landscape occupied, and a value of 0 denoting only a single patch of habitat present within the entire landscape.

Shannon's diversity

Shannon's diversity index is a method of assessing the habitat diversity of a landscape (Blanco *et al.*, 2012). It measures how evenly sized patches of different habitat types are distributed within a landscape. Values start at 0, with only one habitat patch present in the entire landscape, and increases, without limit, as the types of habitat patches increase, and the proportion of the landscape occupied by each type of patch approaches equality. Whilst the absolute index value itself is not particularly meaningful, it does allow us to compare values between different sites, or the same site across different years. Shannon's diversity index was calculated using the '*lsm_l_shdi*' function from *landscapemetrics*, using the formula:

$$SHDI = -\sum_{i=1}^{m} (Pi * lnPi)$$

Configuration

Habitat configuration refers to the shape and spatial arrangement of a landscape and the patches within it. This encompasses simple measures such as habitat size and shape to more complex metrics, such as indices of aggregation and contiguity. Here, we divide configuration into two broad categories - those metrics that describe the landscape (i.e., contiguity, division, etc.) and those that describe habitat patches (i.e., mean patch size, mean shape index, etc.).

Landscape-level metrics

These metrics measure landscape-level effects, such as the distribution of habitat patches across the landscape, and how these patches are connected (or not).

Aggregation index

To quantify the degree to which beneficial habitats were aggregated (i.e., patches occurring near one another) at our project sites we measured the aggregation index of each type of beneficial habitat. This provided an empirical metric describing how close to one another these habitat patches are. Values range between 0 and 100, with 100 being a fully aggregated landscape (i.e., all patches are surrounded by patches of the same habitat type – i.e., like adjacencies). For each category of beneficial habitat, the aggregation index is equal to the number of like adjacencies divided by the theoretical maximum number of like adjacencies. We calculated the aggregation index *via* the '*lsm_c_ai*' function in *landscapemetrics* using the following formula, where g_{ii} is the number of like adjacencies of each habitat class:

$$AI = \left[\frac{g_{ii}}{max - g_{ii}}\right](100)$$

Clumpiness index

Another measure of aggregation we calculated was the clumpiness index of all patches belonging to each category of beneficial habitat. The clumpiness index captures the difference of the measured percentage of like-adjacencies from what we would expect to observe under a spatially random distribution of habitats. The clumpiness index is calculated using the formulae below, where g_{ii} is the number of like-adjacencies, g_{ik} is the class-wise number of all adjacencies, $mine_i$ is the minimum perimeter of the habitat being considered, assuming a maximally clumped arrangement, and P_i is the overall proportion of the landscape occupied by the habitat being considered.

$$G_i = \left(\frac{g_{ii}}{\sum_{k=1}^{m} g_{ik} - mine_i}\right)$$

$$Clumpy = \left[\frac{G_i - P_i}{P_i}\ for\ G_i < P_i\ and\ P_i < .5; else\ \frac{G_i - P_i}{1 - Pi}\right]$$

Normalised landscape shape index

Another method of measuring aggregation that we employed was the normalised landscape shape index of our different types of beneficial habitat. This metric measures the ratio of the edge length of a habitat to its hypothetical minimum and maximum edge lengths. Unlike other aggregation metrics, where higher values denote more aggregation, for this metric a value of 0 denotes a fully aggregated landscape with one squared patch, and a value of 1 denotes a fully dis-aggregated landscape arranged in a checkerboard pattern. This is calculated using the following formula, where e_i is the total edge length, and min e_i and max e_i are the minimum and maximum total edge length respectively.

$$nLSI = \frac{e_i - min\ e_i}{max\ e_i - min\ e_i}$$

Euclidean nearest neighbour distance

We also measured the edge-to-edge distance between patches of beneficial habitat. This allowed us to determine whether the beneficial habitat at our project sites was clustered or evenly dispersed across the landscape – with habitat arranged in clusters having a smaller distance between patches.

Edge density

In a biological context, edges of habitat patches can be both beneficial and detrimental for wildlife species. We calculated the average amount of habitat edge per hectare of our project sites. We utilised the 'lsm_c_ed' function from the '*landscapemetrics*' package, omitting any habitat edge which intersected the boundaries of our sites. Edge density for a type of habitat was calculated using the following formula, where e_{ik} is the total amount of edge, in meters, of each habitat and A is the total landscape area in square meters.

$$ED = \frac{\sum_{k=1}^{m} e_{ik}}{A} * 10000$$

Mean contiguity index

We assessed, for each category of beneficial habitat, the average contiguity (i.e., the spatial connectedness) index within all patches belonging to that category. This is calculated using a layer of 1 m^2 raster cells across the mapped landscape and quantifies the connectivity of cells within a patch to other cells of the same type, with a value of 0 for a cell with no connections, and a value of 1 when a cell is fully connected on all sides. The mean contiguity index was calculated using the '*lsm_c_contig_mn*' function from *landscapemetrics*, where contiguity is calculated according to the following formula: c_{ijr} is the contiguity of cell r in patch ij, a_{ij} is the area of the patch being considered, and v is the sum of 1 m^2 raster cells which fall within a 3x3 window capturing the cells surrounding the considered cell. Within this 3x3 window, horizontal and vertical cells are assigned double the weight than diagonal cells:

$$CONTIG = \frac{\left[\frac{\sum_{r=1}^{z} c_{ijr}}{a_{ij}}\right] - 1}{v - 1}$$

Patch-level metrics

These metrics measure characteristics of patches within the landscape, such as their average size and shape.

Field size

We measured the size of crop cover polygons within our project sites to determine whether there were any differences between the average areas of crops at our demonstration and reference sites. All polygons which matched the 'crop' description as outlined previously were considered, and an average calculated for each site and year combination. These values reflect the basic landscape structures at each project site.

Semi-natural habitat size

To provide additional context to the background habitat at our sites we investigated the average patch size of all categories of semi-natural habitat. This was calculated using the '*lsm_l_area_mn*' function from *landscapemetrics* using a 1 m^2 cell approach as well as manually with polygonal data. Analyses conducted using raster data would count multiple adjoining habitats as a single large patch, whilst polygon data considers each habitat polygon digitised individually and its area in calculations.

Mean Beneficial Patch Size

Another simple method of quantifying the shape of our habitat patches that we investigated was the average patch size of all categories of beneficial habitat. This was calculated using the '*lsm_c_area_mn*' function from *landscapemetrics* for raster cells 1 m^2 in size) as well as using polygon-based vector data.

Mean Shape Index

We calculated the average shape index of patches for each category of beneficial habitat. The shape index of a habitat patch is the ratio between the observed perimeter and the hypothetical minimum perimeter (i.e., the perimeter of a perfect square of the same area); it is a measure of patch complexity. The value of the index increases without limit as the shape of habitat patches becomes more complex. The average shape index was calculated using '*lsm_c_shape_mn*' from *landscapemetrics via* the following formula, where p_{ij} is the perimeter of the patch:

$$SHAPE = \frac{p_{ij}}{min\ p_{ij}}$$

Mean Perimeter-Area Ratio

We also calculated the average perimeter-area ratio of each habitat patch for each category of beneficial habitat. Small values indicate the average patch perimeter is equal to the patch area (i.e., the patch is a small square), with the metric increasing as the perimeter increases (i.e., the patch becomes more complex and angular) This was calculated using the '*lsm_c_para_mn*' function in *landscapemetrics*, following the formula below where p_{ij} is the patch perimeter in meters, and a_{ij} is the area in square meters:

$$PARA = \frac{p_{ij}}{a_{ij}}$$

Mean Fractal Dimension Index

To quantify the complexity of the shapes of our habitat patches we calculated the average fractal dimension index of each category of beneficial habitat. Values have a maximum of 2 and a minimum of 1, with larger values indicating patches with more complex and irregular shapes. The fractal dimension index was calculated using '*lsm_c_frac_mn*' from the *landscapemetrics* package, using the following formula where β is the slope of the regression of the area against the perimeter (i.e., the relationship between area and perimeter):

$$PAFRAC = \frac{2}{\beta}$$

Core Area Index

To provide a measure of the quality of habitats established at our project sites we measured the mean proportion of each habitat patch which could be defined as core area. We defined the core area of a habitat patch as any part of a beneficial habitat patch that was at least 10 meters away from the nearest outside edge of the habitat patch. The result of this was that a patch of beneficial habitat would have to be at least 20 meters wide to be able to contain any core habitat. We chose a 10 m distance as nests of grey partridges in habitats over 20 m in width are subject to fewer losses due to predation (Gottschalk and Beeke, 2014).

Core Area Percentage of Landscape

Similarly, we calculated for each site the percentage of the landscape occupied by core habitat, using the same definition of core habitat as above. We calculated this using the following formula, where a_{ij}^{core} is the core area in square meters, and A is the total landscape area in square meters:

$$CPLAND = \left(\frac{\sum_{j=1}^{n} a_{ij}^{core}}{A}\right) * 100$$

Number of farmers

We aimed to determine the relationship between the number of farmers present on our demonstration site and the aggregation of our beneficial habitat. We took the number of farmers to be a static value across time, and tested the maximal value of the aggregation index, clumpiness index, and normalised landscape shape index values for each demonstration site. Both the predictor and response variable were log10-ratio transformed. Linear regression was carried out using the *'lm'* function in R version 4.2.0 (R Core Team, 2022).

Statistical analysis

Compositional analysis (undertaken in SYSTAT version 12.00.08; SYSTAT Software, Inc., 2007) was used to compare habitats of demonstration sites with reference sites, testing for an effect of time.

To determine the significance of our metrics we performed, unless specified otherwise, two-way repeated measures ANOVAs with a Bonferroni correction in which our paired demonstration-reference sites were considered our unique identifiers, comparing between site type (i.e., demonstration or reference) and sample year. In cases where our metrics are returned as proportions, these values were transformed to angles (i.e., square root, arcsine transformed). For all metrics calculated using the '*landscapemetrics'* package, values were lntransformed (x+0.001) before analysis took place. We completed analysis in Genstat version 23.1.0.651, using repeated measurement analysis with REML (residual maximum likelihood) to test for interactions between site type and time (as a linear variable) through the duration of the project, controlling for the fact that measurements were taken sequentially on the same site. Site pair was included as a random factor in the model. Considering the vast number of metrics we analysed, we chose to restrict our significance threshold to $p < 0.01$ to reduce the likelihood of Type I errors.

Results

The landscape analysis of the demonstration areas within the PARTRIDGE project involved the calculation and comparison of many descriptive landscape metrics. We summarise the results of this analysis below (Table 2). The detail of the significant results from the analysis are presented in the Results section, with illustrations throughout using mapped data from individual sites. The detail of non-significant results can be found in Appendix 2. Maps of our project sites, organised by site, year, country can be found in Appendix 3.

Table 2. A summary of the results of analysis undertaken on the composition of habitats within the PARTRIDGE project sites. Each habitat category (e.g., broad, beneficial) was analysed using Wilk's lambda. Significant ($p < 0.01$) results are highlighted in bold, with details following in the Results section.

Habitat Types	p-values	
	Site Type	Time
Broad habitat	**< 0.001**	0.962
Beneficial habitat	**< 0.001**	0.680

Table 3. A summary of the results of analysis undertaken on the metrics describing the habitat changes across the PARTRIDGE project areas. For each metric different habitat groupings were analysed (e.g., broad, beneficial, non-crop, etc.) using two-way repeated measures ANOVAs. Significant ($p < 0.01$) results are highlighted in bold, with details following in the Results section. Details of non-significant results can be found in Appendix 2.

Metric	Habitat Type	p-values		
		Site Type * Time	Site Type	Time
Composition				
Habitat coverage (%)	Non-crop habitat	0.013	**0.004**	**< 0.001**
	Summer beneficial habitat	**0.003**	**< 0.001**	**< 0.001**
	Winter beneficial habitat	0.721	0.056	0.941
	Summer hare habitat	**0.006**	**< 0.001**	**0.001**
	Winter hare habitat	0.025	**< 0.001**	**< 0.001**
Heterogeneity				
Richness	Summer beneficial habitat	0.277	**0.010**	**< 0.001**
	Winter beneficial habitat	0.120	**0.003**	**< 0.001**
	Crop habitat	0.065	0.423	**< 0.001**
	Semi-natural habitat	0.580	0.127	**< 0.001**
Simpson's diversity	Summer beneficial habitat	0.015	0.126	**0.006**
	Winter beneficial habitat	0.364	0.024	0.065
	Summer crop habitat	0.680	0.414	0.528
	Winter crop habitat	0.641	0.028	**0.002**
	Semi-natural habitat		*Did not converge.*	
Shannon's diversity	Summer beneficial habitat	0.018	0.087	**0.004**
	Winter beneficial habitat	0.437	**0.004**	0.027

Table 3. (cont.)

	Configuration			
Aggregation index	Nesting habitat	0.922	0.011	**< 0.001**
	Brood-rearing habitat	0.788	0.011	0.889
	Overwinter cover habitat	0.014	0.028	0.994
Clumpiness index	Nesting habitat	0.891	0.014	**< 0.001**
	Brood-rearing habitat	0.916	0.013	0.668
	Overwinter cover habitat	0.011	0.036	0.959
Normalized landscape shape index	Nesting habitat	0.017	**0.005**	**< 0.001**
	Brood-rearing habitat	0.536	**0.003**	0.375
	Overwinter cover habitat	0.020	0.029	0.854
Euclidean nearest neighbour distance	Nesting habitat	0.508	0.025	0.190
	Brood-rearing habitat	0.408	**0.008**	**0.003**
	Overwinter cover habitat	0.338	0.188	0.107
	Nesting to brood-rearing habitat	0.051	**0.005**	**< 0.001**
Edge density	Nesting habitat	0.735	0.012	0.011
	Brood-rearing habitat	0.817	**0.004**	**< 0.001**
	Overwinter cover habitat	0.521	**0.004**	0.264
Mean contiguity index	Nesting habitat	0.621	0.138	0.109
	Brood-rearing habitat	**0.010**	0.744	0.195
	Overwinter cover habitat	0.161	0.303	0.844
Mean field size	Crop habitat	0.343	0.226	0.799
Mean polygon area – vector	Semi-natural habitat	**0.006**	0.560	**< 0.001**
Mean patch area – raster	Semi-natural habitat	0.399	0.588	**< 0.001**
Mean polygon area – vector	Nesting habitat	0.927	0.058	0.028
	Brood-rearing habitat	0.395	0.130	0.141
	Overwinter cover habitat	**0.006**	**< 0.001**	0.646
Mean patch area – raster	Nesting habitat	0.037	0.198	0.018
	Brood-rearing habitat	0.045	0.101	0.113
	Overwinter cover habitat	0.335	0.907	0.671
Mean shape index	Nesting habitat	0.658	0.102	**0.002**
	Brood-rearing habitat	0.085	0.878	0.368
	Overwinter cover habitat	0.477	0.064	0.684
Mean perimeter-area ratio	Nesting habitat	0.707	0.046	0.069
	Brood-rearing habitat	0.467	0.990	0.204
	Overwinter cover habitat	0.126	0.559	0.715
Mean fractal dimension index	Nesting habitat	0.758	0.450	**0.005**
	Brood-rearing habitat	0.059	0.357	0.059
	Overwinter cover habitat	0.141	0.455	0.504
Core area index	Nesting habitat	0.069	0.053	0.034
	Brood-rearing habitat	0.087	**0.003**	0.039
	Overwinter cover habitat	0.856	0.620	0.184
Core area percentage of landscape	Nesting habitat	**0.005**	**< 0.001**	**< 0.001**
	Brood-rearing habitat	**0.010**	**< 0.001**	**0.001**
	Overwinter cover habitat	0.535	0.254	0.845

Composition

Broad habitat composition

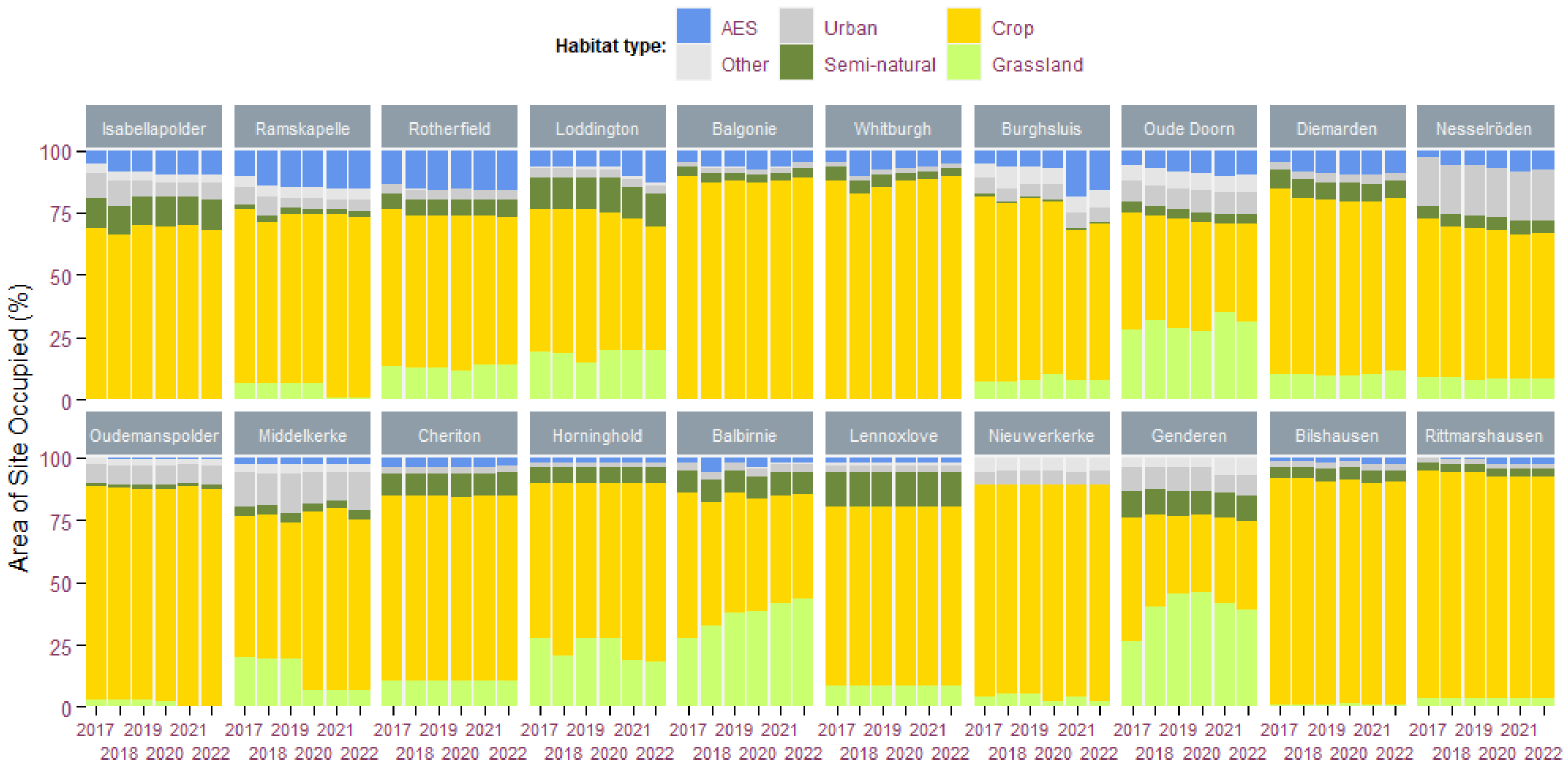


Figure 1: Changes in the composition of broad habitat types at demonstration (top) and their paired reference sites (bottom) over the six years of the PARTRIDGE project.

Overall, there was a significant difference between demonstration areas in comparison to reference areas in their habitat composition (Wilks's Lambda 0.487, $F_{5, 54} = 11.40$ $p < 0.001$), with no significant change through time (Wilks's Lambda 0.982, $F_{5, 54} = 0.20$, $p = 0.962$). Ranking matrices (Table 3) indicated that demonstration sites had higher proportions of agri-environmental habitats than reference sites, with reference sites holding a higher proportion of grassland and cropped habitats than demonstration sites. Less clear-cut was the proportion of other habitat, urban, and semi-natural habitats, with a tendency for demonstration areas to hold higher proportions of these habitats.

Table 4. Ranking matrices obtained from the compositional analysis and the habitat selection ratios, comparing the overall habitat composition of demonstration and reference sites.

	Reference sites						
Demonstration sites	AES	Other	Urban	Semi-natural	Crop	Grassland	Rank
AES		+++	+++	+++	+++	+++	1
Other	---		+++	+	+++	+++	2
Urban	---	---		+	+++	+++	3
Semi-natural	---	-	-		+++	+++	4
Crop	---	---	---	---		+++	5
Grassland	---	---	---	---	---		6

Beneficial habitat composition

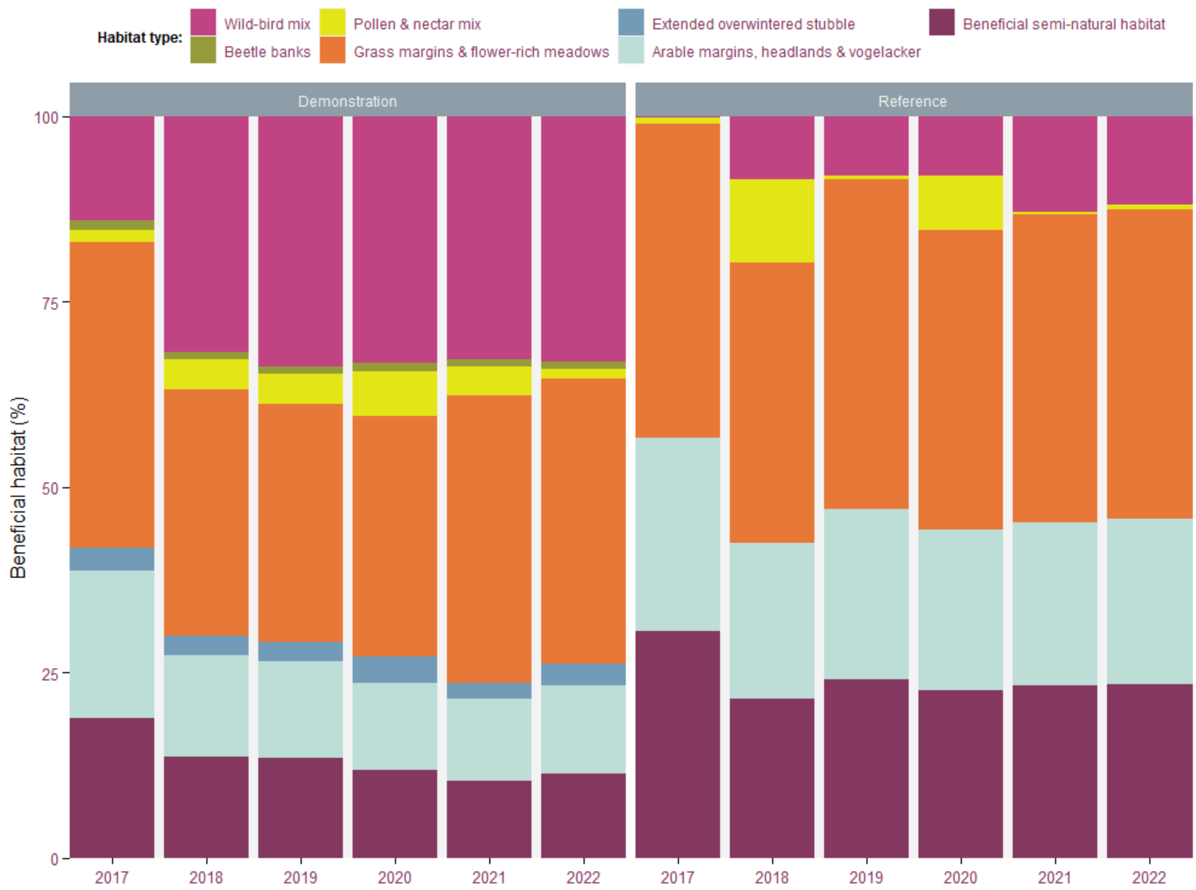


Figure 2: The average composition of types of beneficial habitats at demonstration and reference sites over the six years of the PARTRIDGE project.

We compared the composition of beneficial habitats between demonstration and reference sites. There was no significant effect by year (Wilks's Lambda 0.930, $F_{6, 53}$ = 0.66, p = 0.680). Overall, there was a significant difference between the demonstration and reference sites in the proportion of different beneficial habitats (Wilks's Lambda 0.299, $F_{6, 53}$ = 21.09, p < 0.001). Demonstration sites had higher proportions of wild-bird mix and beetle banks making up their beneficial habitats than reference sites, while references sites had higher proportions of beneficial semi-natural habitat. The proportions of the other types of beneficial habitat did not show a clear difference between the different types of sites.

Table 5. Ranking matrices obtained from the compositional analysis and the habitat selection ratios, comparing the beneficial habitat composition of demonstration and reference sites.

	Reference sites							
Demonstration sites	Wild-bird mix	Beetle banks	Pollen & nectar mix	Grass margins & flower-rich meadows	Extended overwintered stubbles	Arable margins, headlands & vogelacker	Beneficial semi-natural habitat	Rank
Wild-bird mix		+++	+++	+++	+++	+++	+++	1
Beetle banks	---		+++	+++	+++	+++	+++	2
Pollen & nectar mix	---	---		+	+	+++	+++	3
Grass margins & flower-rich meadows	---	---	-		+	+	+++	4
Extended overwintered stubbles	---	---	-	-		+	+++	5
Arable margins, headlands & vogelacker	---	---	---	-	-		+	6
Beneficial semi-natural habitat	---	---	---	---	---	-		7

Non-crop area (%)

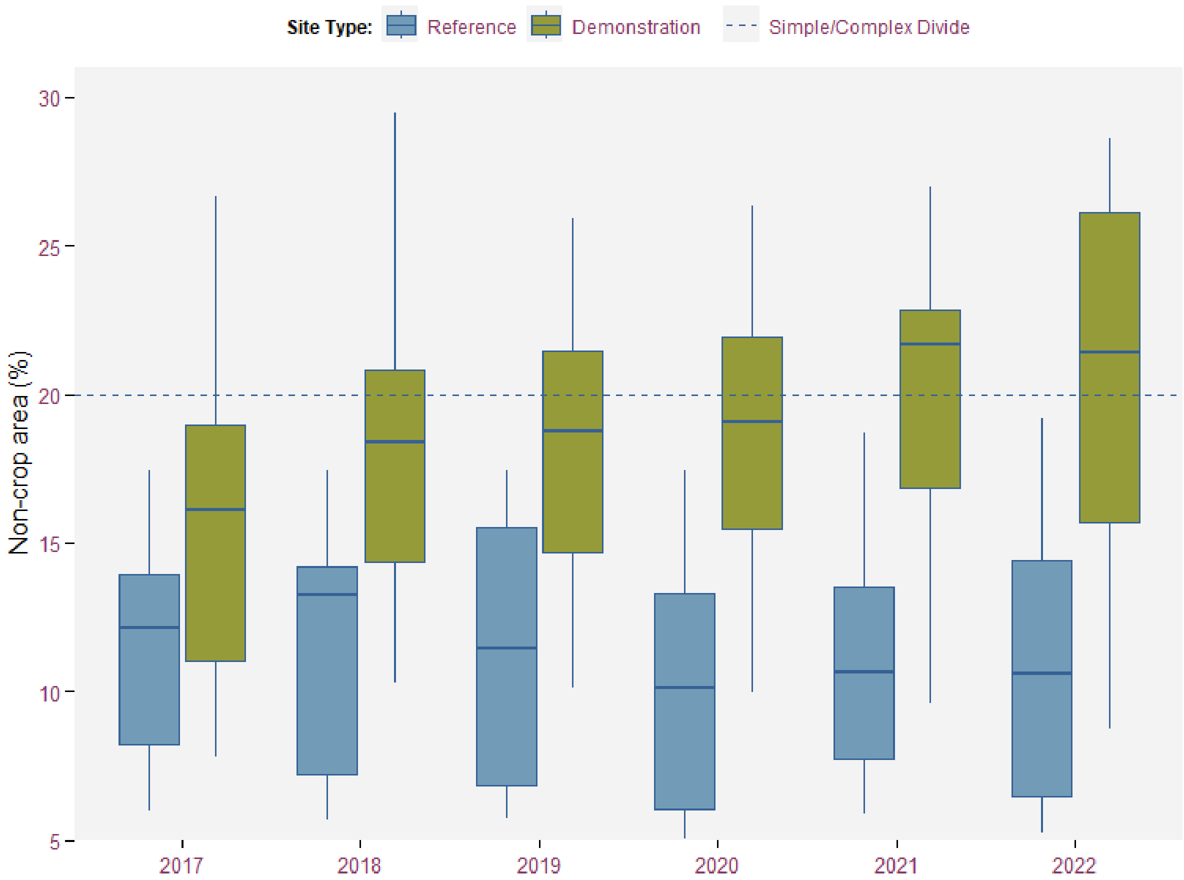


Figure 3: The percentage of non-crop area on demonstration and reference sites over the six years of the PARTRIDGE project. The 20% level, considered to divide simple and complex habitats (Tscharntke, Batáry and Dormann, 2011), is provided for comparison.

We did not find a statistically significant two-way interaction between site type and time ($F_{(1, 98)} = 6.44$, $p = 0.013$, Figure 3), when investigating the percentage of project sites covered by non-crop habitat. Considering the main effect of time, we found that the percentage of non-crop habitat over all sites changed significantly over the course of the project ($F_{(1, 98)} = 22.86$, $p < 0.001$). Investigating the effect of site type, we found that demonstration sites were, on average, composed of significantly greater non-crop habitat than reference sites ($F_{(1, 18)} = 11.23$, $p = 0.004$). In the last three years of the project our demonstration sites had more non-crop habitat, on average, with an additional 8.6% of their area non-crop habitat – compared to reference sites (Figure 4).

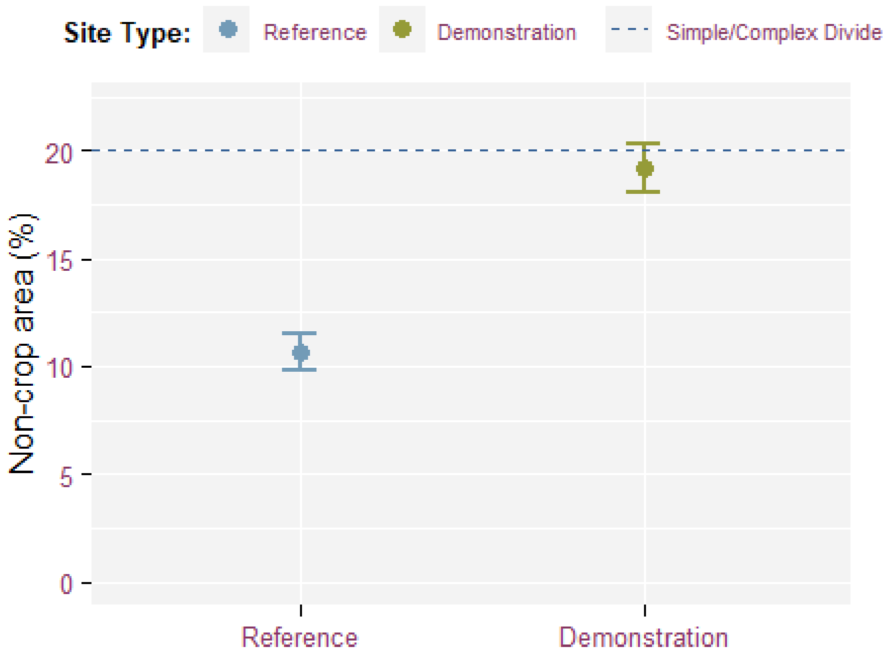
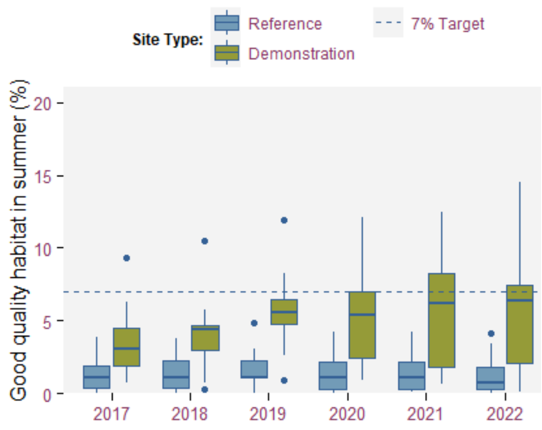


Figure 4: The average percentage (± standard error) of non-crop area on our demonstration and reference sites in the final three years of the PARTRIDGE project (2020-2022). The 20% level, considered to divide simple and complex habitats, is provided for comparison.

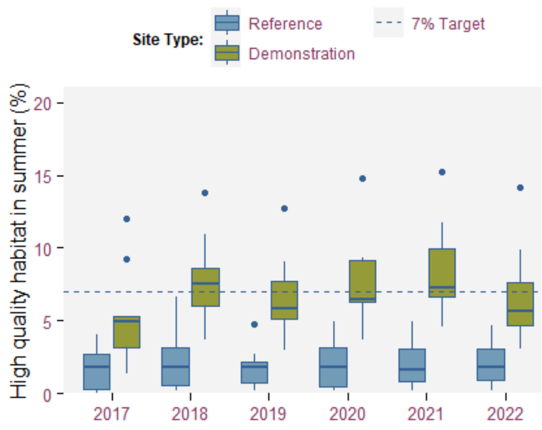
By the end of the project the average non-crop area across all our ten demonstration sites failed to surpass the 20% level, the point at which they would be considered 'complex' landscapes (Tscharntke, Batáry, and Dormann, 2011). However, six of the ten demonstration sites did surpass this threshold by the end of the project, namely Burghsluis (in 2021 & 2022), Isabellapolder (2017 to 2022), Loddington (2017 to 2022), Oude Doorn (2018 to 2022), Ramskapelle (2018 to 2022), and Rotherfield (2018 to 2022). None of the ten reference sites reached the 20% threshold.

Beneficial habitat (%) for farmland birds

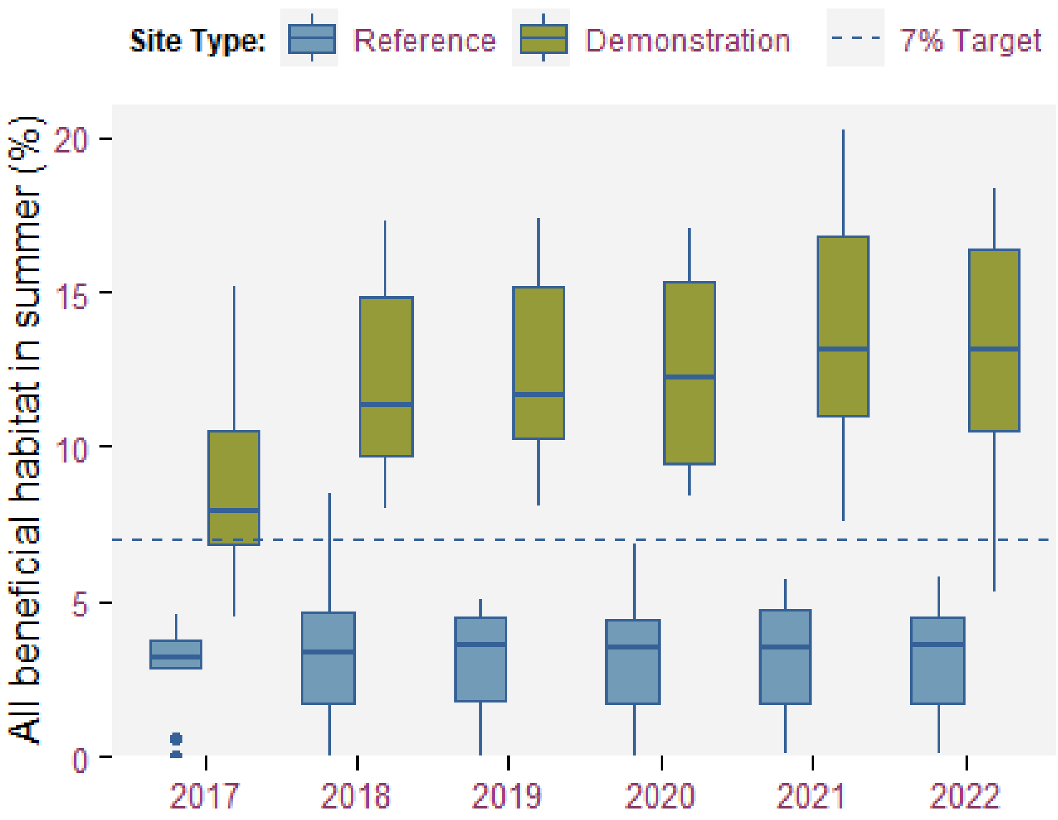
Summer Habitat



(a) 'Good quality' habitat.



(b) 'High quality' habitat.



(c) All beneficial summer habitat.

Figure 5: The percentage of demonstration and reference sites occupied by (a) good summer habitat, (b) high-quality summer habitat and (c) all beneficial summer habitat combined over the six years of the PARTRIDGE project. The 7% target is provided for comparison.

The interaction between site type and time for the percentage of projects sites covered by all beneficial habitats was significant ($F_{(1, 98)} = 9.50$, $p = 0.003$, Figure 5). With the area occupied by beneficial habitat at our demonstration sites increasing significantly ($F_{(1, 49)} = 14.56$, $p < 0.001$) by 3.9% throughout the total span of the project, compared to no significant change at the reference sites ($F_{(1, 49)} = 1.04$, $p = 0.313$). The effect of this significant change at our demonstration sites can be seen clearly by averaging the amount of beneficial habitat in the final three years of the project (Figure 6).

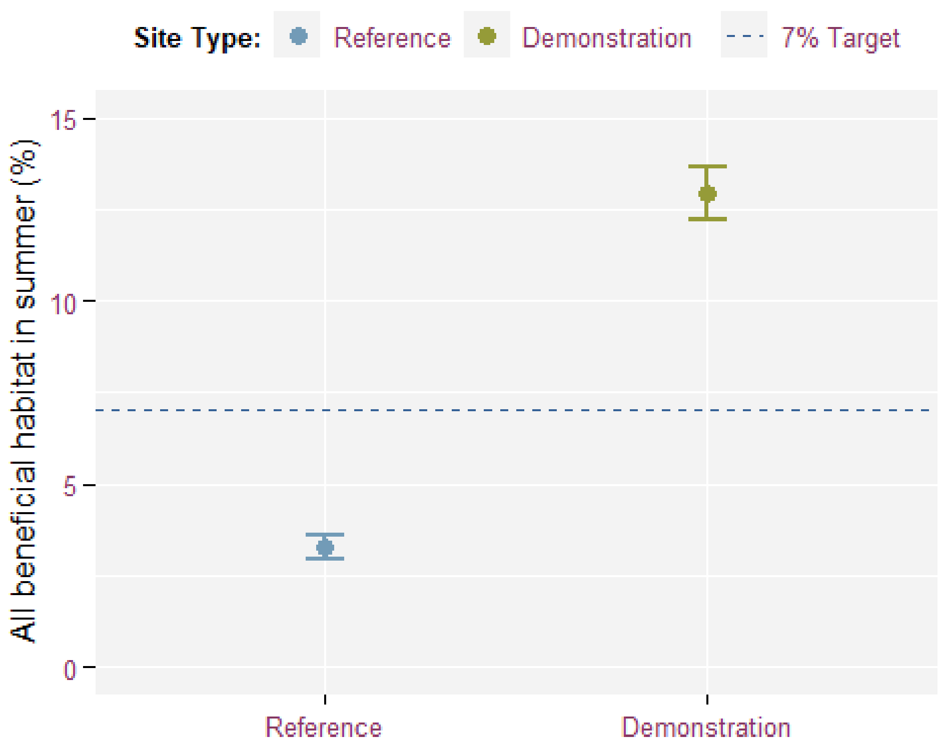
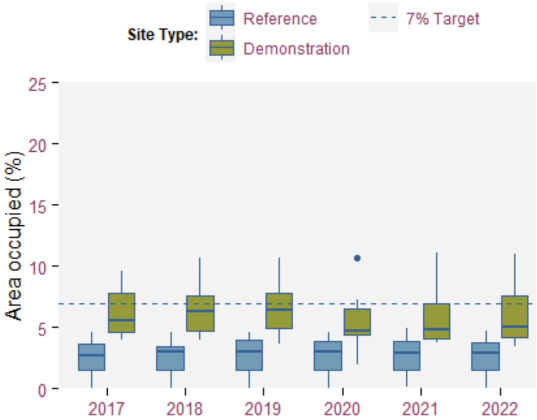


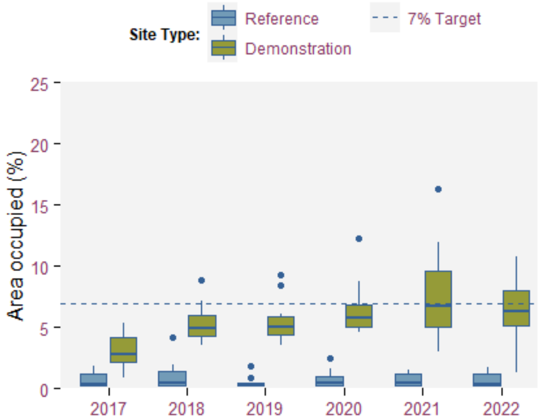
Figure 6: The average percentage of beneficial summer habitat (± standard error) at our demonstration and reference sites in the final three years of the PARTRIDGE project (2020 - 2022). The 7% target is provided for comparison.

Beneficial habitat (%) for brown hare

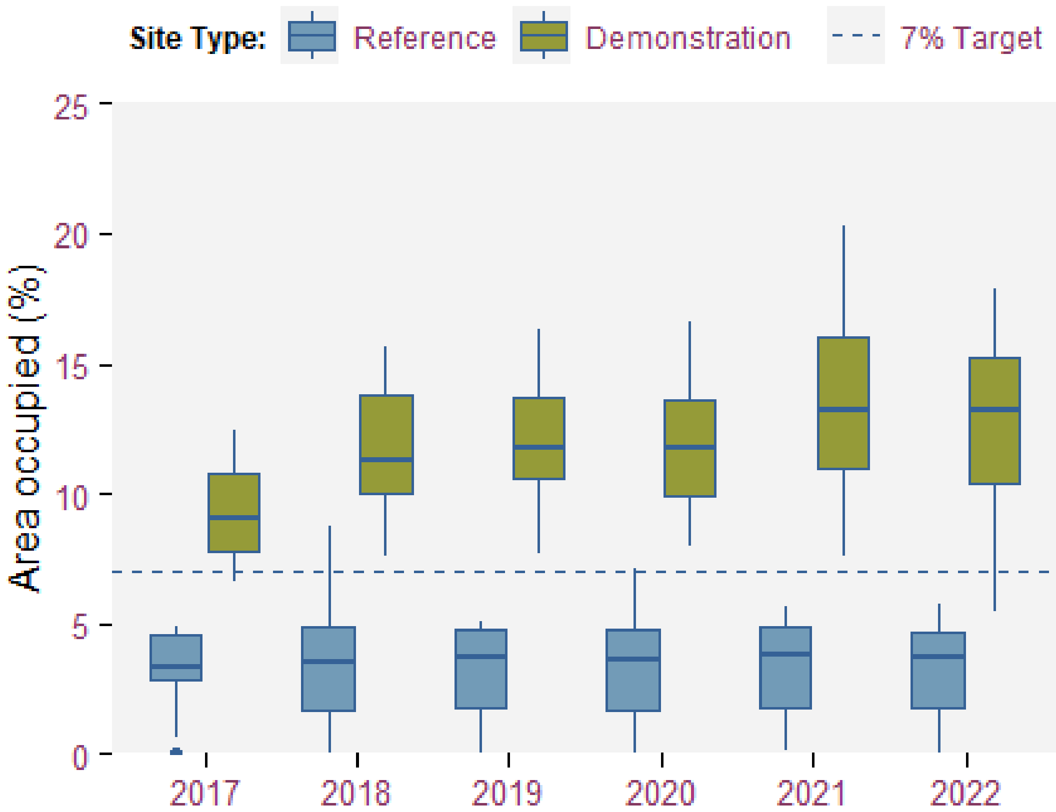
Summer habitat



(a) 'Good quality' habitat.



(b) 'High quality' habitat.



(c) All beneficial summer habitat.

Figure 7: Changes in proportion of project sites occupied by beneficial summer habitat for hare over time.

There was a significant interaction between the effects of site type and time on the proportion of beneficial summer habitat for brown hare at our project sites ($F_{(1, 98)}$ = 7.97, p =

0.006, Figure 7). Values at our demonstration sites increased significantly ($F_{(1, 49)} = 11.30$, $p < 0.002$), by 3.3% over the full course of the project, whilst values at our reference sites did not significantly change ($F_{(1, 49)} = 0.35$, $p = 0.557$).

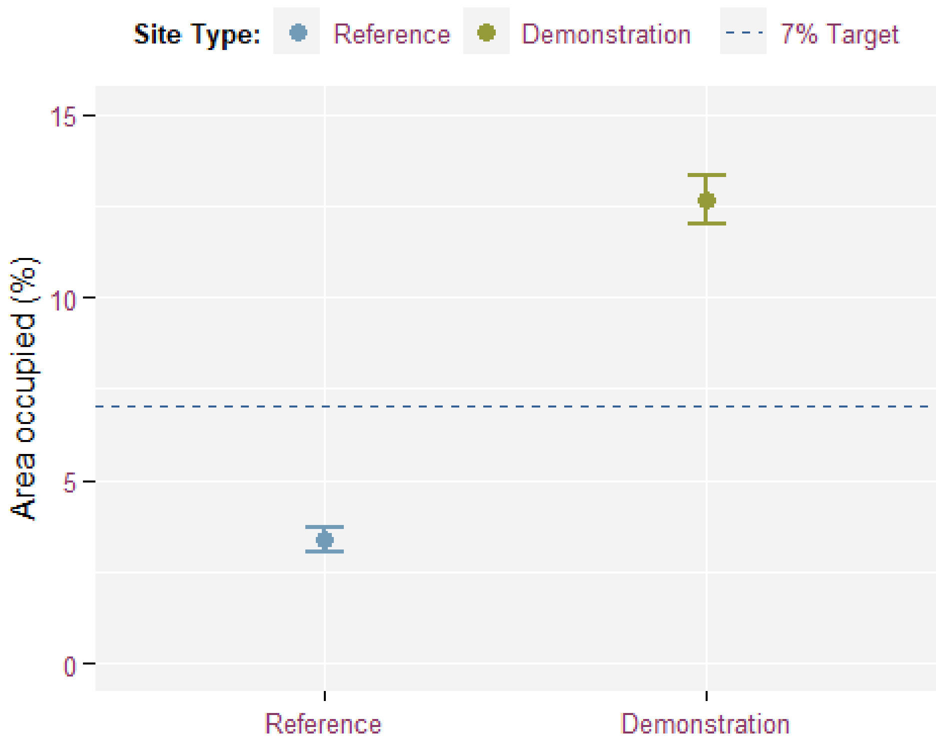
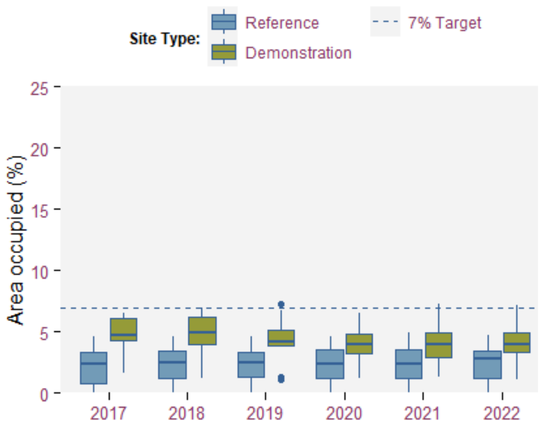
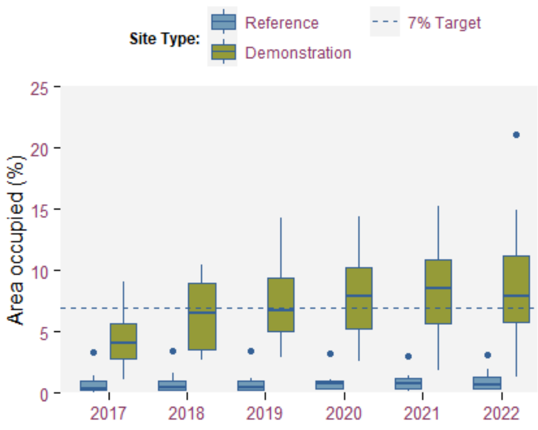


Figure 8: The difference in the proportion of beneficial summer habitat for brown hare at our project sites in the final three years of the project (2020 - 2022).

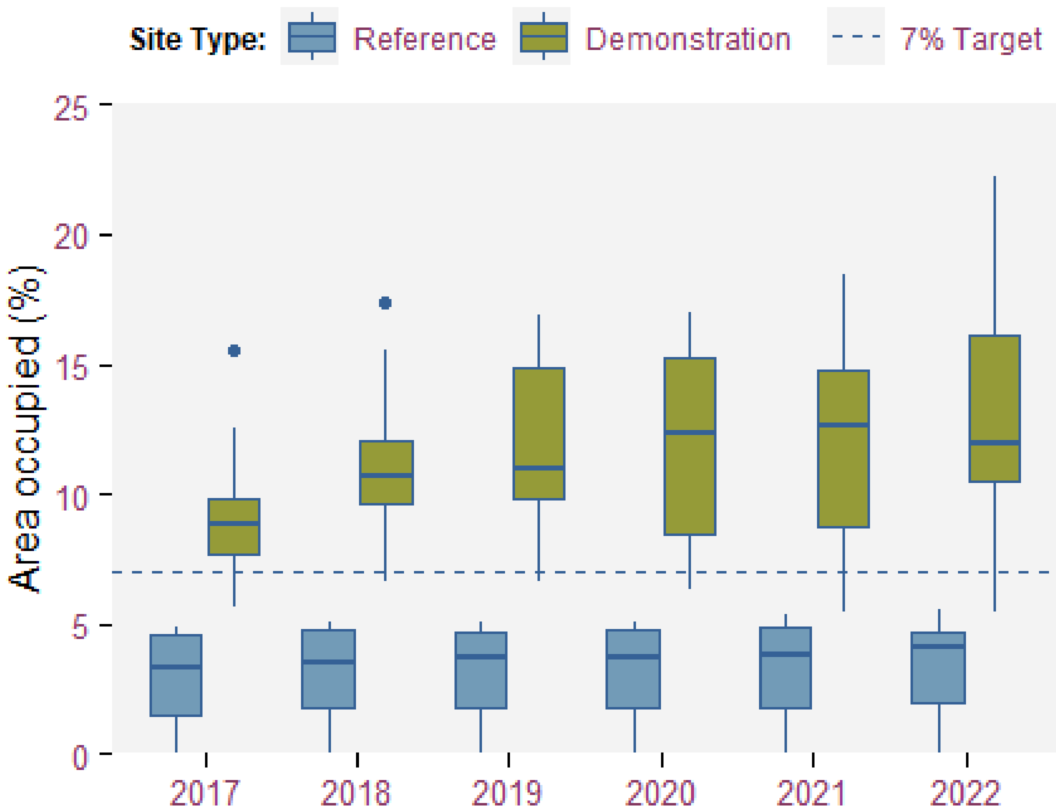
Winter habitat



(a) 'Good quality' habitat.



(b) 'High quality' habitat.



(c) All beneficial winter habitat.

Figure 9: Changes in proportion of project sites occupied by beneficial winter habitat for hare over time.

There was no significant interaction between site type and time on the proportion of beneficial winter habitat for brown hare at our project sites ($F_{(1, 98)} = 5.20$, $p = 0.025$, Figure 9). We did, however, find that our demonstration sites had significantly more beneficial winter habitat for brown hare than our reference sites ($F_{(1, 9)} = 58.69$, $p < 0.001$), with an average of 12.3% beneficial habitat covering our demonstration sites, compared to 3.3% of our reference sites in the final 3 years of the project (Figure 10). Overall, across all sites, these values changed significantly through time ($F_{(1, 98)} = 15.07$, $p < 0.001$), decreasing by an average of 0.5% throughout the duration of the project.

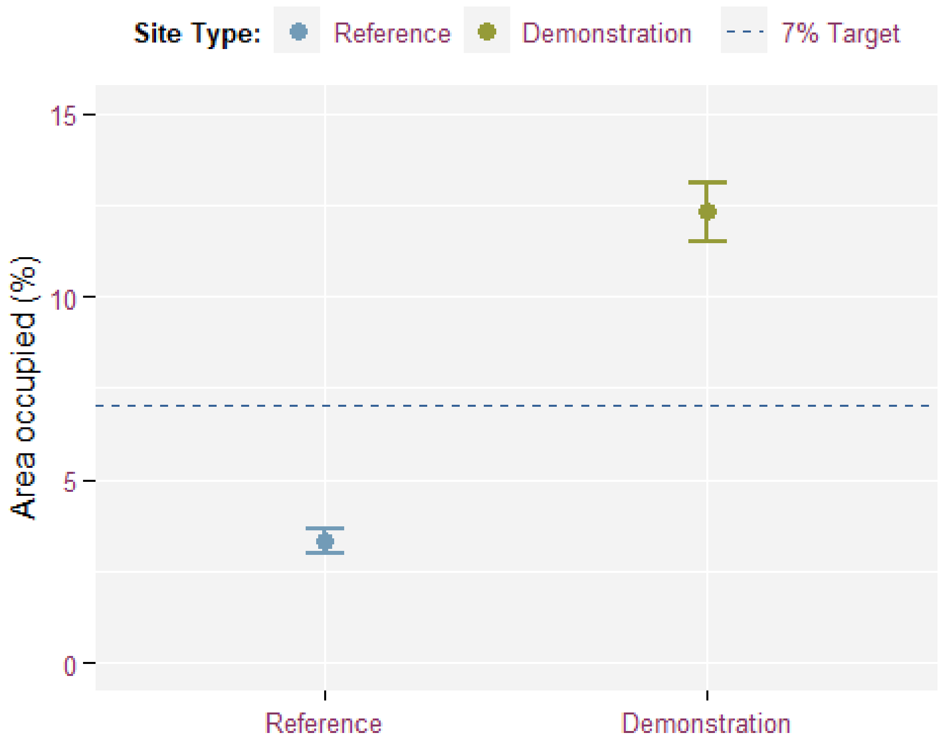


Figure 10: The difference in the proportion of beneficial winter habitat for brown hare at project sites in the final three years of the project (2020 - 2022).

Heterogeneity

Patch richness

Beneficial habitat (unique habitats per area)

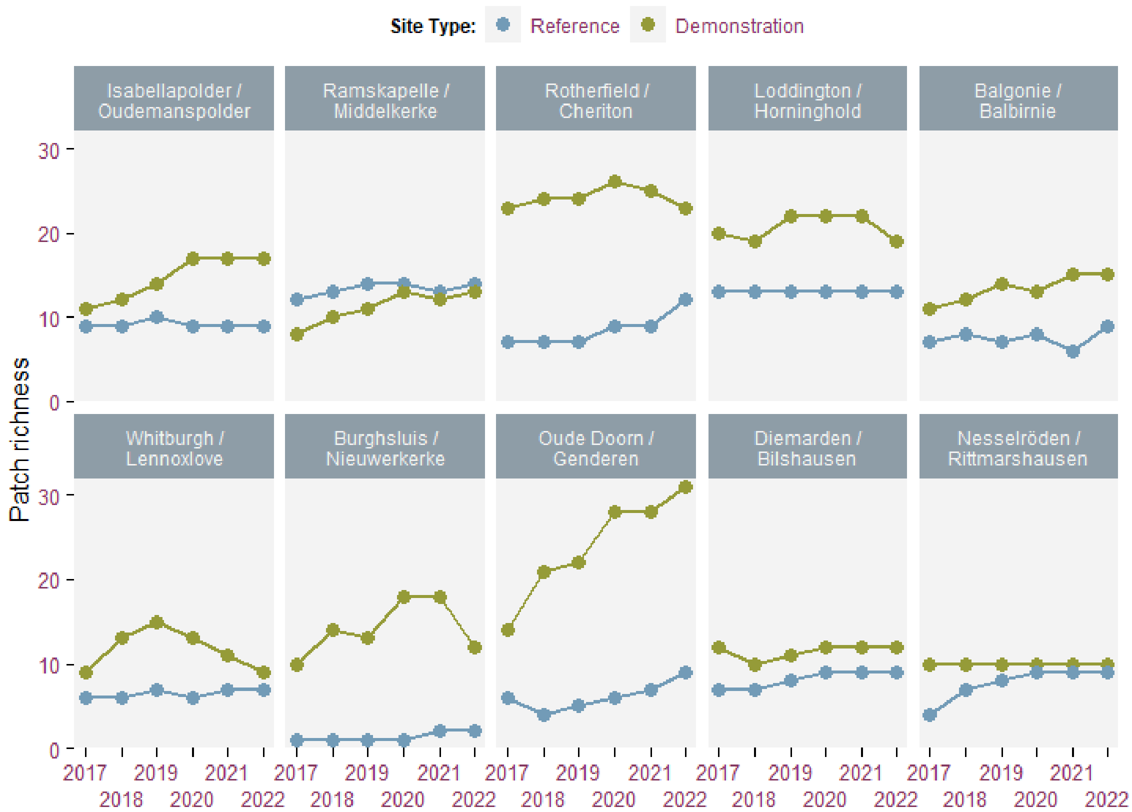


Figure 11: Patch richness of summer beneficial habitat (measured as the number of unique beneficial habitats present on the summer maps) over the six years of the PARTRIDGE project.

We measured patch richness as the number of unique beneficial habitats present on our project sites. We were unable to detect a significant interaction between site type and time in the richness of beneficial summer habitat ($F_{(1, 98)} = 1.19$, $p = 0.277$, Figure 11). We did, however, find that the richness of beneficial summer habitat was significantly higher at our demonstration sites ($F_{(1, 9)} = 10.41$, $p = 0.010$), with an average of 8.1 additional unique habitats present on demonstration sites, in comparison to reference sites, in the final three years of the project (Figure 12). In addition, we found that the richness of project sites overall increased significantly throughout the project ($F_{(1, 98)} = 44.69$, $p < 0.001$).

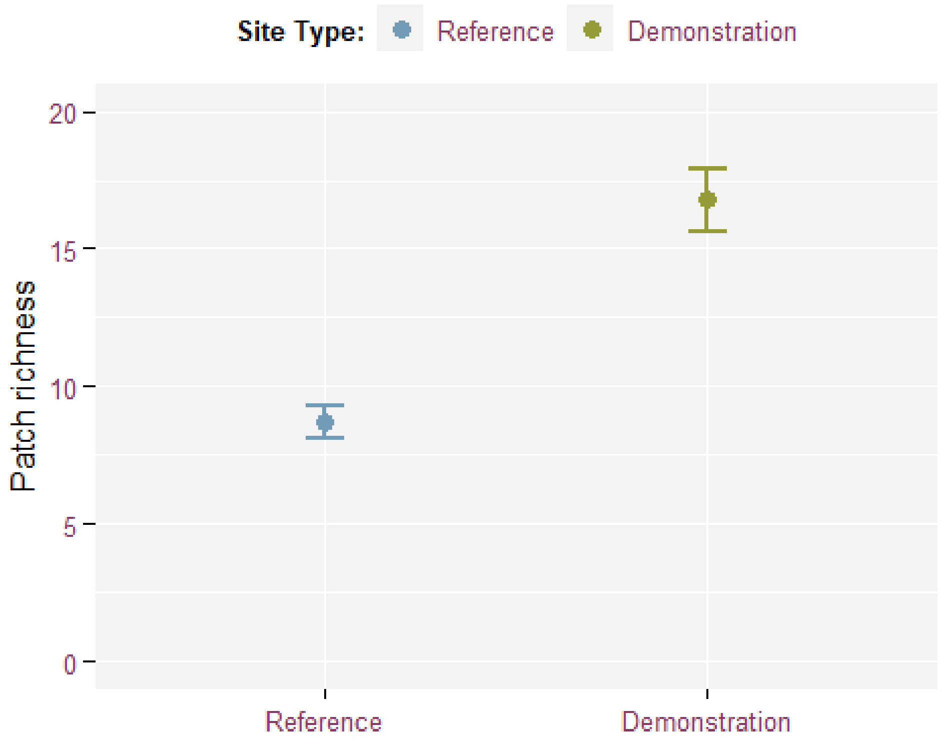


Figure 12: Average (± standard error) patch richness of summer beneficial habitat (measured as the number of unique habitats present) on our demonstration and reference sites in the final three years of the PARTRIDGE project (2020 - 2022).

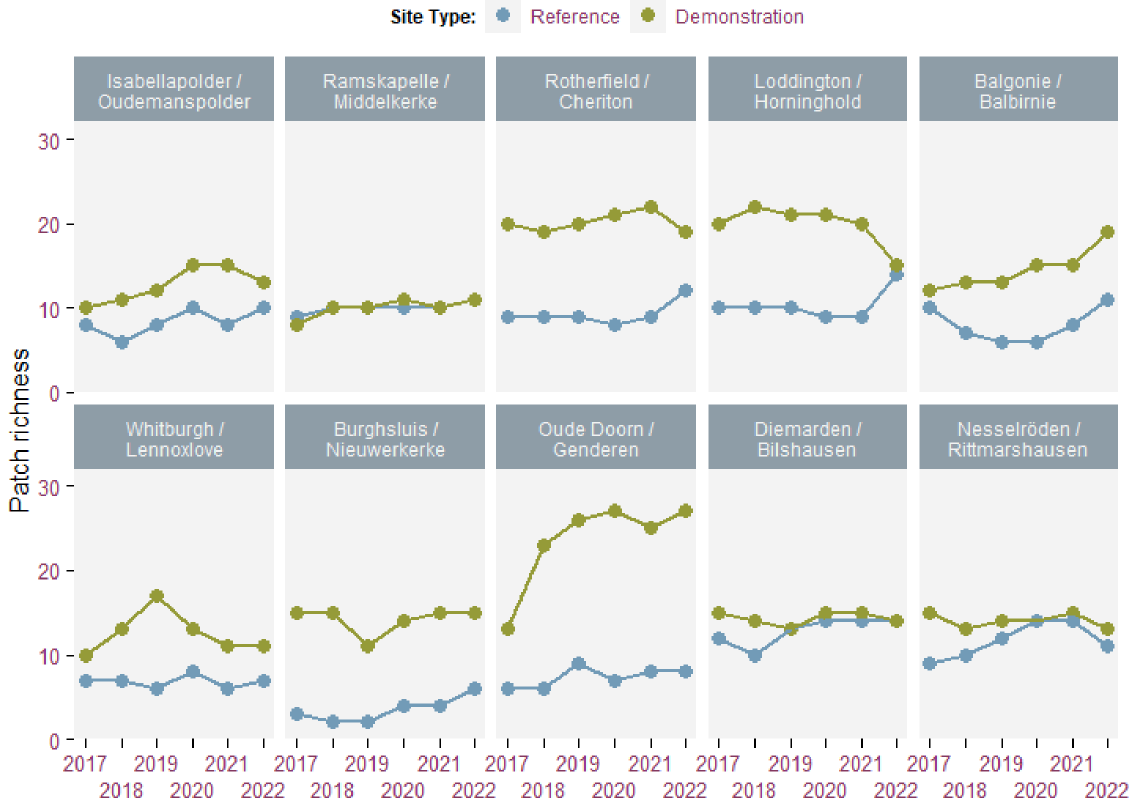


Figure 13: Patch richness of winter beneficial habitat (measured as the number of unique beneficial habitats present on the winter maps) over the six years of the PARTRIDGE project.

We also investigated the richness of winter beneficial habitat at our project sites, finding that the interaction between site type and time was not significant ($F_{(1, 98)}$ = 2.46, p = 0.120, Figure 13). We found that the simple main effect of site type was significant ($F_{(1, 9)}$ = 17.08, p = 0.003), with winter beneficial habitat significantly richer at our demonstration sites throughout the entirety of the project, with 6.7 more unique habitats than our reference sites in the final three years of the project (Figure 14). The effect of time overall was also significant ($F_{(1, 98)}$ = 20.55, p < 0.001), with richness increasing by an average of 2.1 unique habitats over the course of the project.

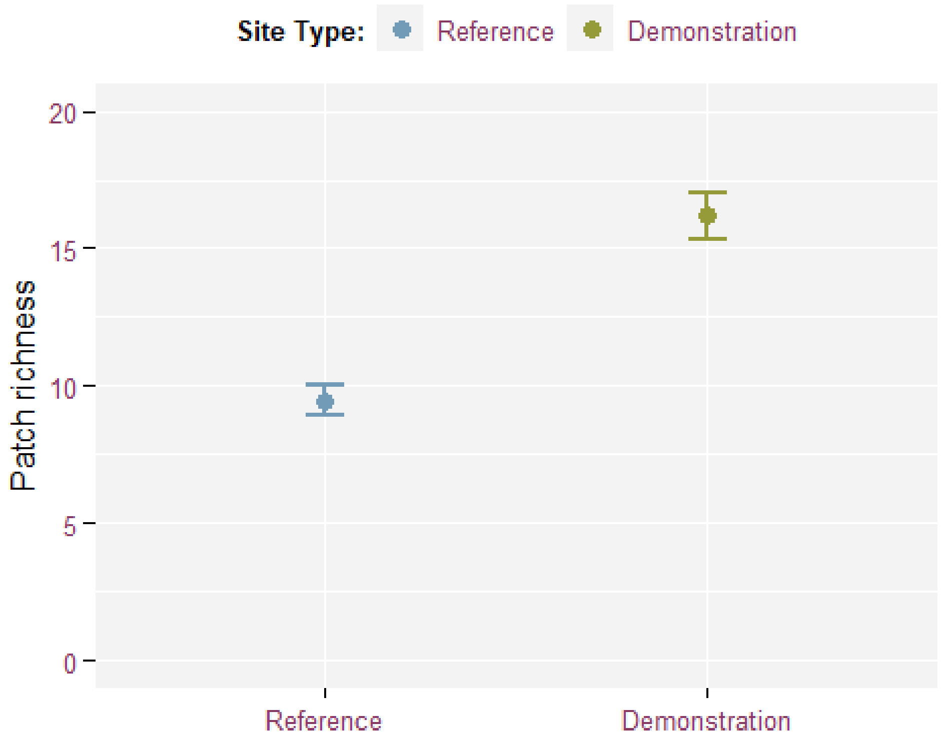


Figure 14: The average patch richness (± standard error) of beneficial winter habitat on our demonstration and reference sites in the final three years of the PARTRIDGE project (2020 – 2022).

Crop habitat (unique crops per area)

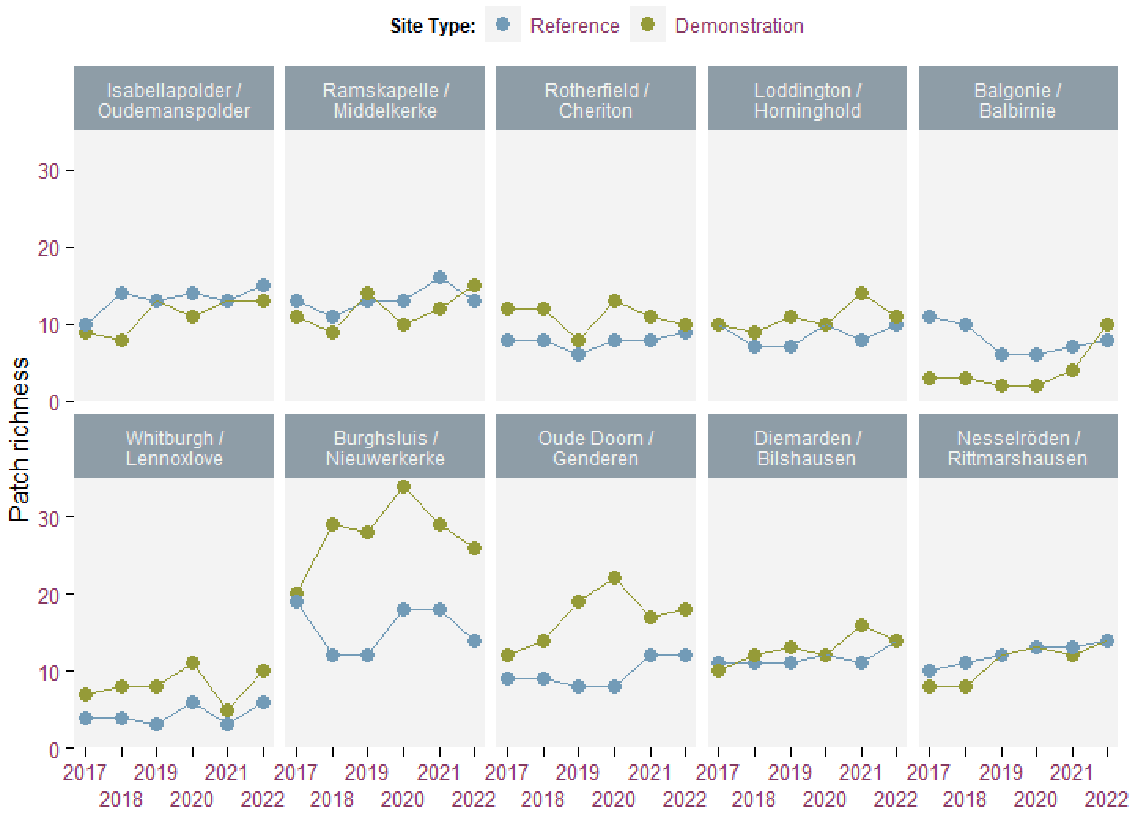


Figure 15: Changes in richness of cropping over time.

We did not find a significant interaction between site type and year on the richness of summer cropping at our project sites ($F_{(1, 98)}$ = 3.47, p = 0.065, Figure 15). We did find, however, that crop richness changed significantly over time ($F_{(1, 98)}$ = 18.68, p < 0.001), with richness increasing by 2.5 (i.e., an additional 2.5 unique crop types) overall. There was no significant difference between the crop richness at our demonstration and reference sites ($F_{(1, 9)}$ = 0.70, p = 0.423, Figure 16).

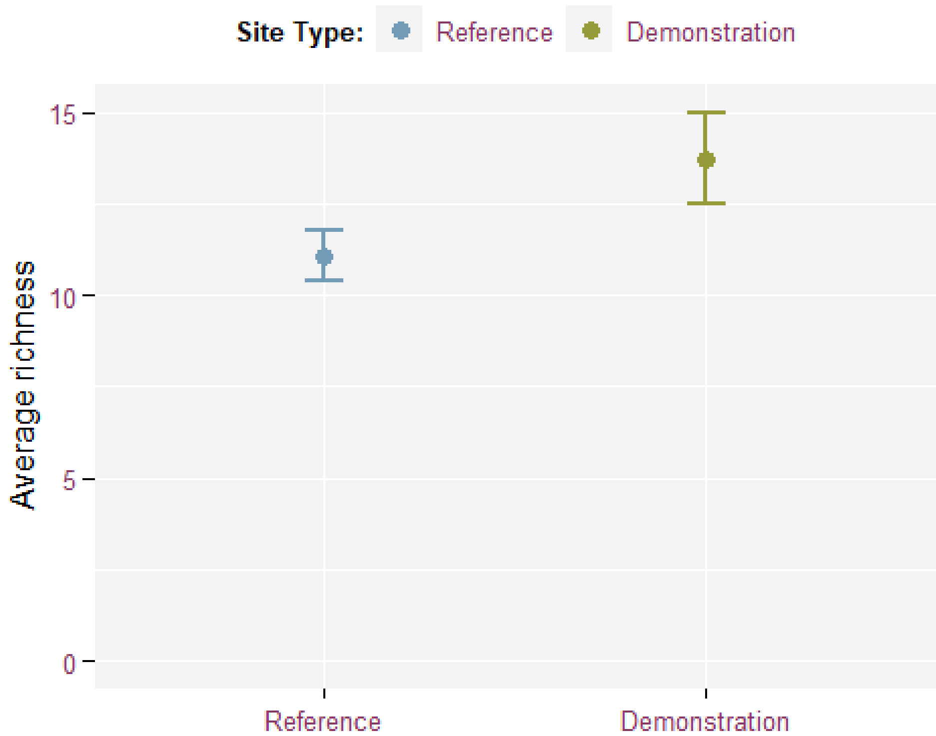


Figure 16: The average richness of crops (± standard error) of our demonstration and reference sites in the final three years of the PARTRIDGE project (2020 - 2022).

Semi-natural habitat

Figure 17: Changes in richness of semi-natural habitat over time.

We did not find a significant interaction between the effects of site type and time on the richness of semi-natural habitat at our project sites ($F_{(1, 98)}$ = 3.67, p = 0.058, Figure 17). We did not detect a significant difference between the richness of semi-natural habitat between our demonstration and reference sites ($F_{(1, 9)}$ = 2.83, p = 0.127), with the average richness of demonstration sites across the final three years of the project found to be 1.7 above those of reference sites in the same period (Figure 18). Values at Lennoxlove were identical to those at Whitburgh, which is why they appear to be missing from the above graph. We did, however, find a significant effect of time on the richness of these habitats ($F_{(1, 98)}$ = 11.79, p < 0.001), with richness increasing by, on average, 0.5 (i.e., 0.5 additional unique habitats) over the course of the project.

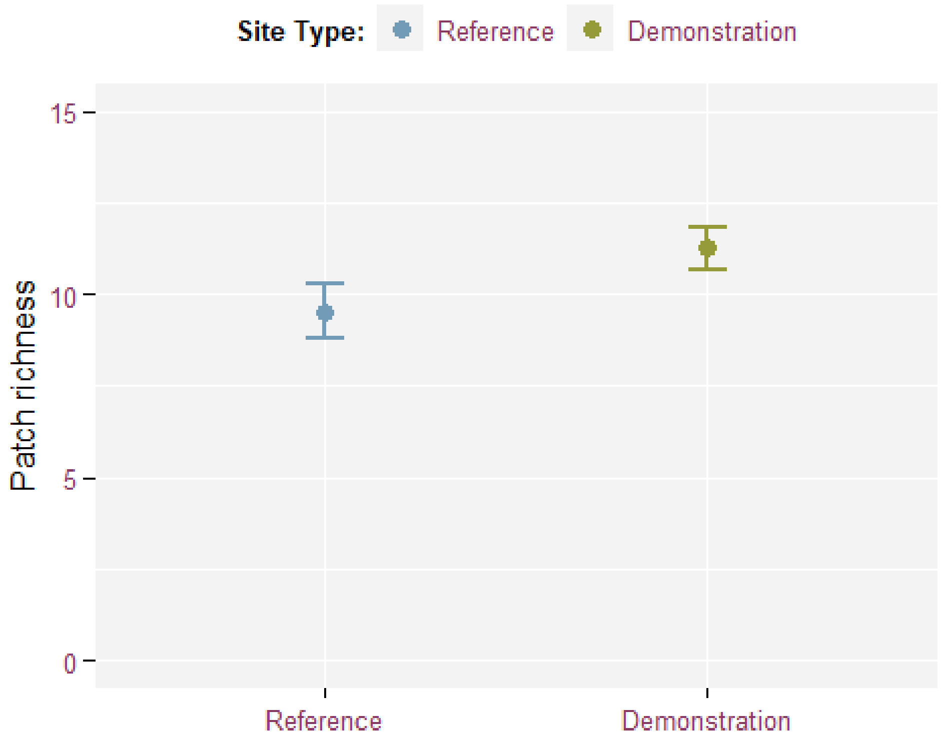


Figure 18: The difference in the richness of semi-natural habitat of our project sites in the final three years of the project (2020 - 2022).

Simpson's diversity

Beneficial habitat

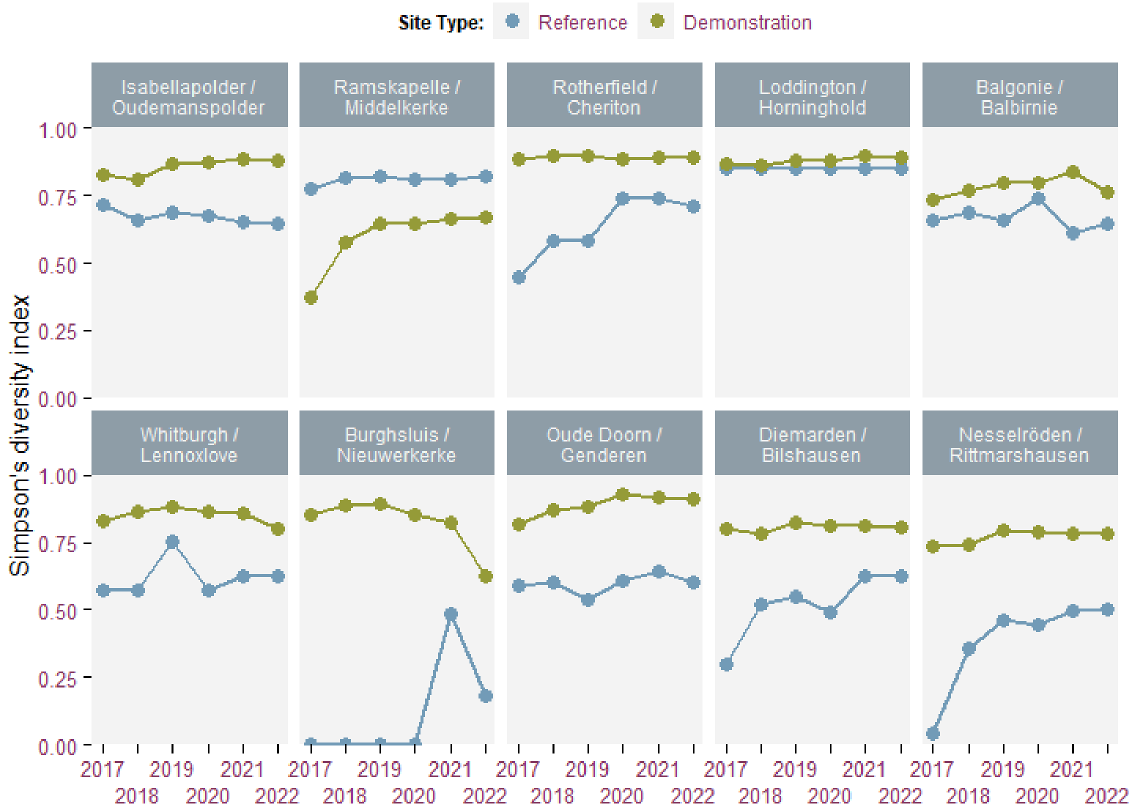


Figure 19: The Simpson's diversity index of beneficial summer habitat at demonstration and reference sites over the six years of the PARTRIDGE project.

There was no significant interaction between site type and time in the Simpson's diversity of beneficial summer habitat ($F_{(1, 98)}$ = 6.11, p = 0.015, Figure 19). There was no significant effect of site type on habitat ($F_{(1, 18)}$ = 2.57, p = 0.126), with the average Simpson's diversity index of our demonstration sites 0.2 above that of our reference sites in the final three years of the project (Figure 20). We were, however, able to detect a significant overall change in the Simpsons diversity index of these habitats through time ($F_{(1, 98)}$ = 7.77, p = 0.006), with index values increasing by an average of 0.1 throughout the duration of the project.

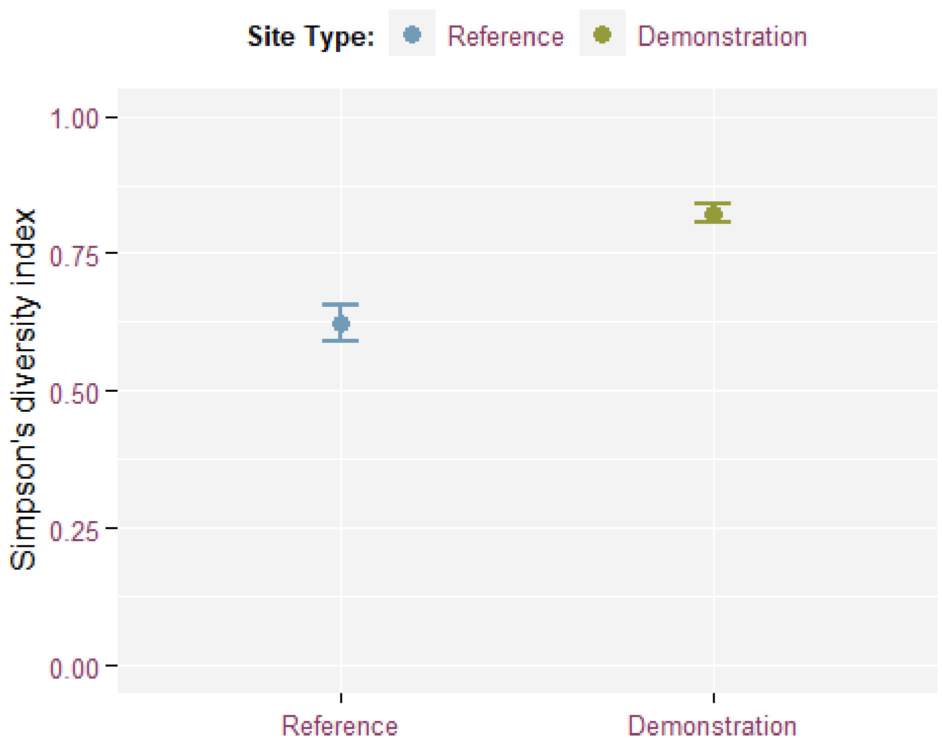


Figure 20: The average Simpson's diversity index (± standard error) of the beneficial summer habitat on our demonstration and reference sites in the final three years of the PARTRIDGE project (2020 - 2022).

Crop habitat

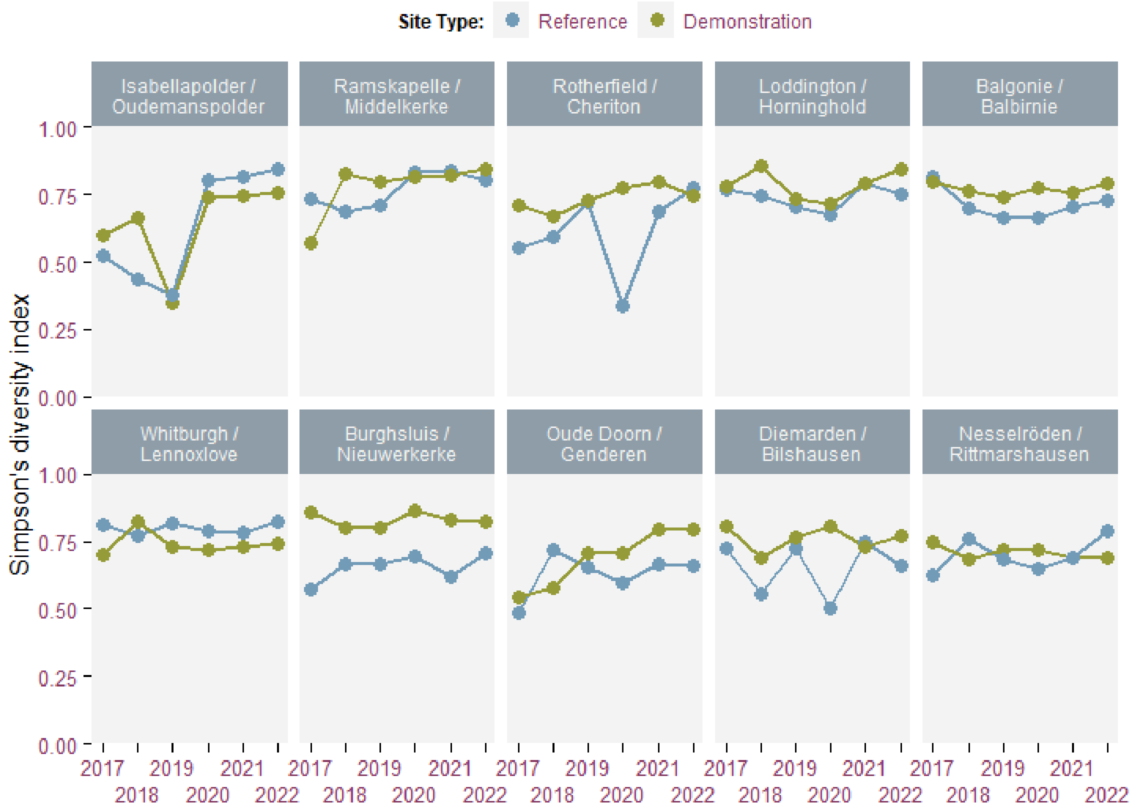


Figure 21: The Simpson's diversity index of winter cropping at demonstration and reference sites over the six years of the PARTRIDGE project.

As with summer crops, we also found no significant interaction between site type and time when considering the Simpson's diversity of winter crops at our project sites ($F_{(5, 45)}$ = 0.22, p = 0.641, Figure 21). There was no significant difference between site types on winter crop diversity ($F_{(1, 9)}$ = 6.84, p = 0.028), with average index values at our demonstration sites just 0.06 greater than those at our reference sites in the final three years of the project (Figure 22). There was an overall increase in the Simpson's diversity index of winter crops ($F_{(1,99)}$ = 10.55, p = 0.002), with index values increasing by an average of 0.08 throughout the duration of the project.

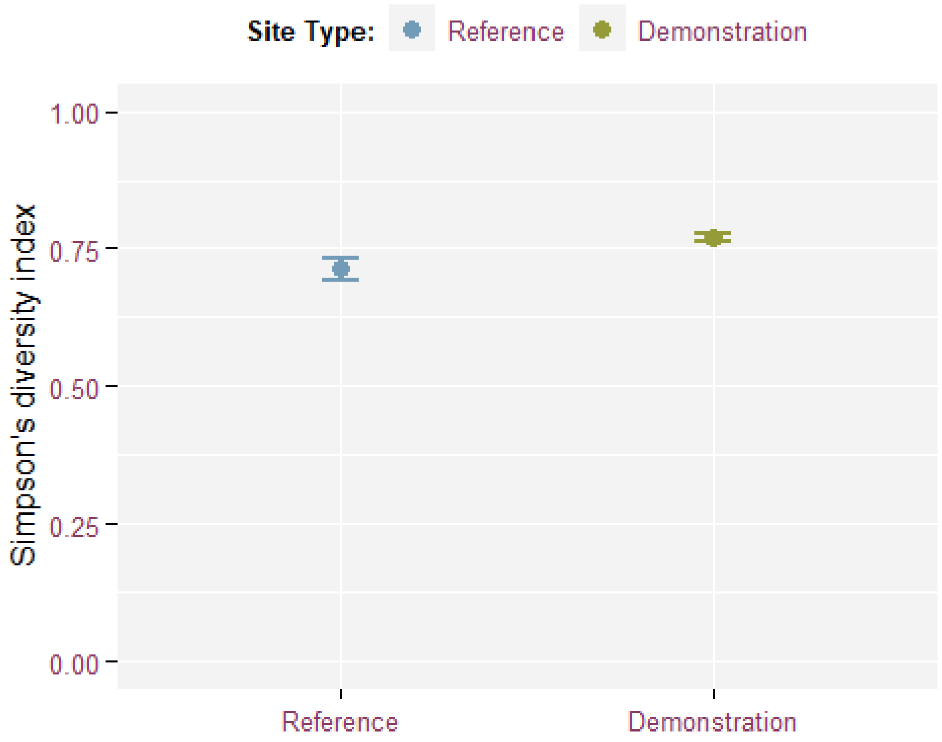


Figure 22: The average Simpson's diversity index of winter crops (± standard error) at our demonstration and reference sites in the final three years of the PARTRIDGE project (2020 - 2022).

Shannon's diversity

We found no significant interactions between site type and time on the richness and Simpson's diversity of crop and semi-natural habitat, nor significant effects on these individual variables. Therefore, we chose to omit these habitat types from further analysis of landscape heterogeneity.

Beneficial habitat

Figure 23: The Shannon's diversity index of beneficial summer habitat at demonstration and reference sites over the six years of the PARTRIDGE project.

There was no significant interaction between site type and time when considering the Shannon's diversity of beneficial summer habitat at our project sites ($F_{(1, 98)} = 5.82$, $p = 0.018$, Figure 23). There was also no significant effect of site type on the Shannon's diversity index of these habitats ($F_{(1, 18)} = 3.28$, $p = 0.087$, Figure 24), but we did find a significant change the Shannon's diversity index through time ($F_{(1, 98)} = 8.63$, $p = 0.004$) with index values increasing by, on average, 0.2 throughout the duration of the project.

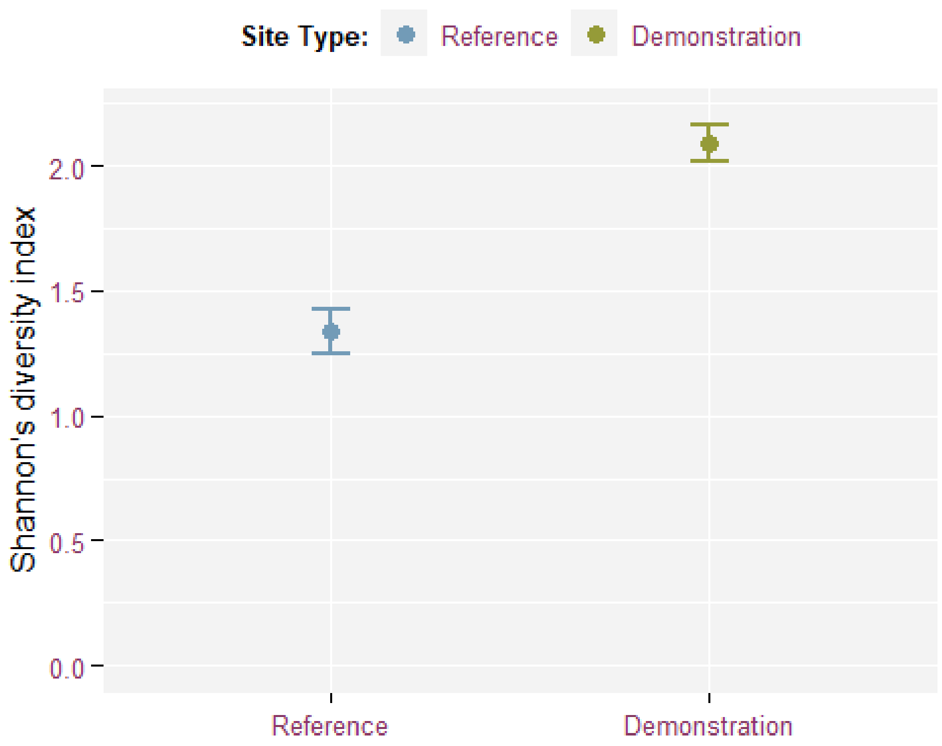


Figure 24: The average Shannon's diversity index (± standard error) of beneficial summer habitat on our demonstration and reference sites in the final three years of the PARTRIDGE project (2020 - 2022).

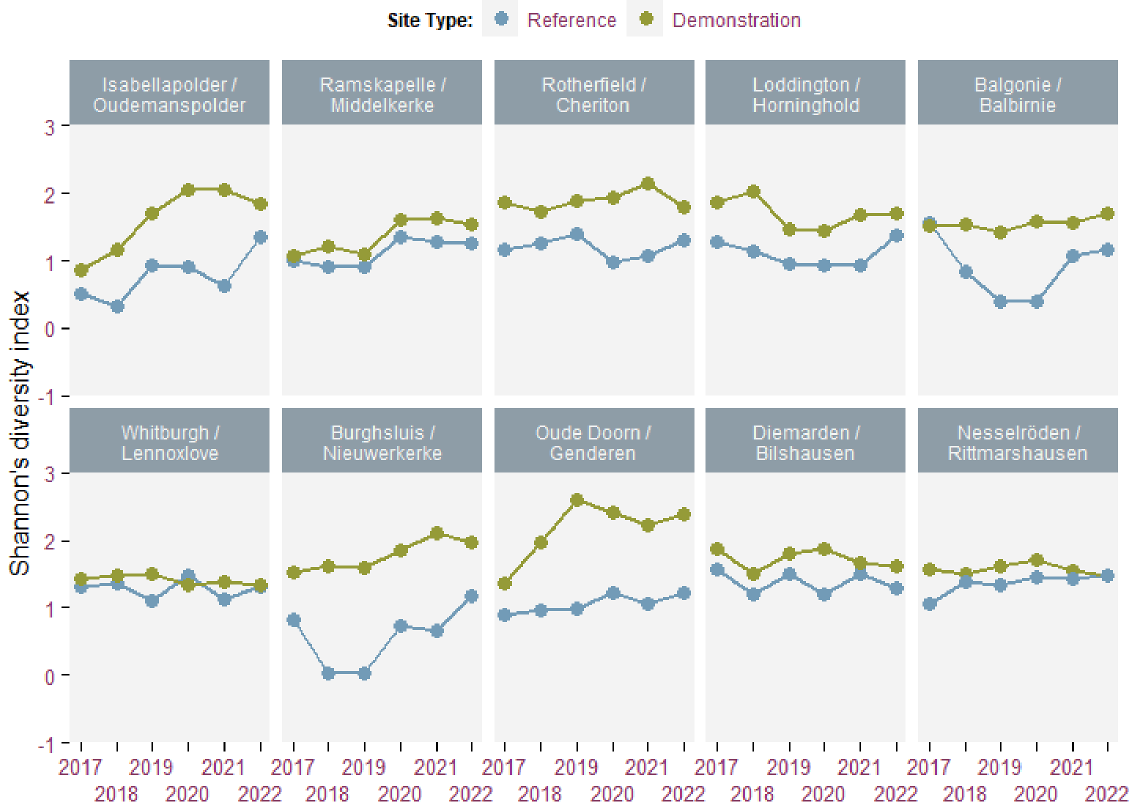


Figure 25: The Shannon's diversity index of beneficial winter habitat at demonstration and reference sites over the six years of the PARTRIDGE project.

There was no significant interaction between time and site type in the Shannon's diversity index of beneficial winter habitats at our project sites ($F_{(1, 98)} = 0.61$, $p = 0.437$, Figure 25). The Shannon's diversity index of beneficial winter habitats differed significantly between the demonstration and reference sites ($F_{(1, 18)} = 11.14$, $p = 0.004$), with demonstration sites having average index value 0.62 greater than those of our reference sites in the final three years of the project, a difference of 43% (Figure 26). There was no significant change through time ($F_{(1, 98)} = 5.01$, $p = 0.027$).

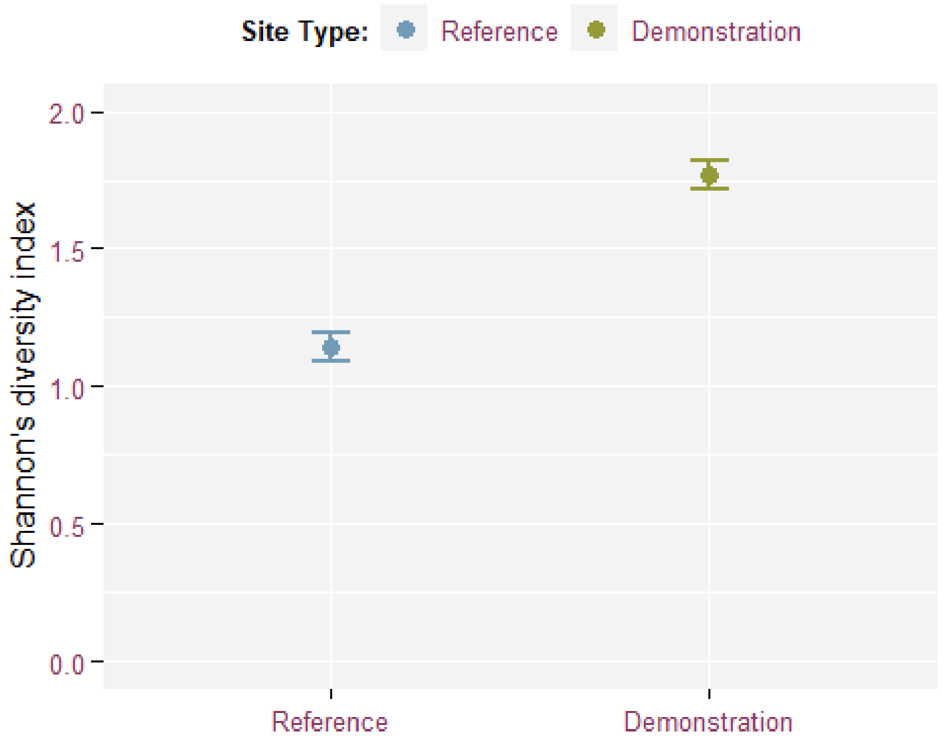


Figure 26: The average Shannon’s diversity index of beneficial winter habitat (± standard error) on our demonstration and reference sites in the final three years of the PARTRIDGE project (2020 - 2022).

Configuration

Landscape-level metrics

Aggregation index

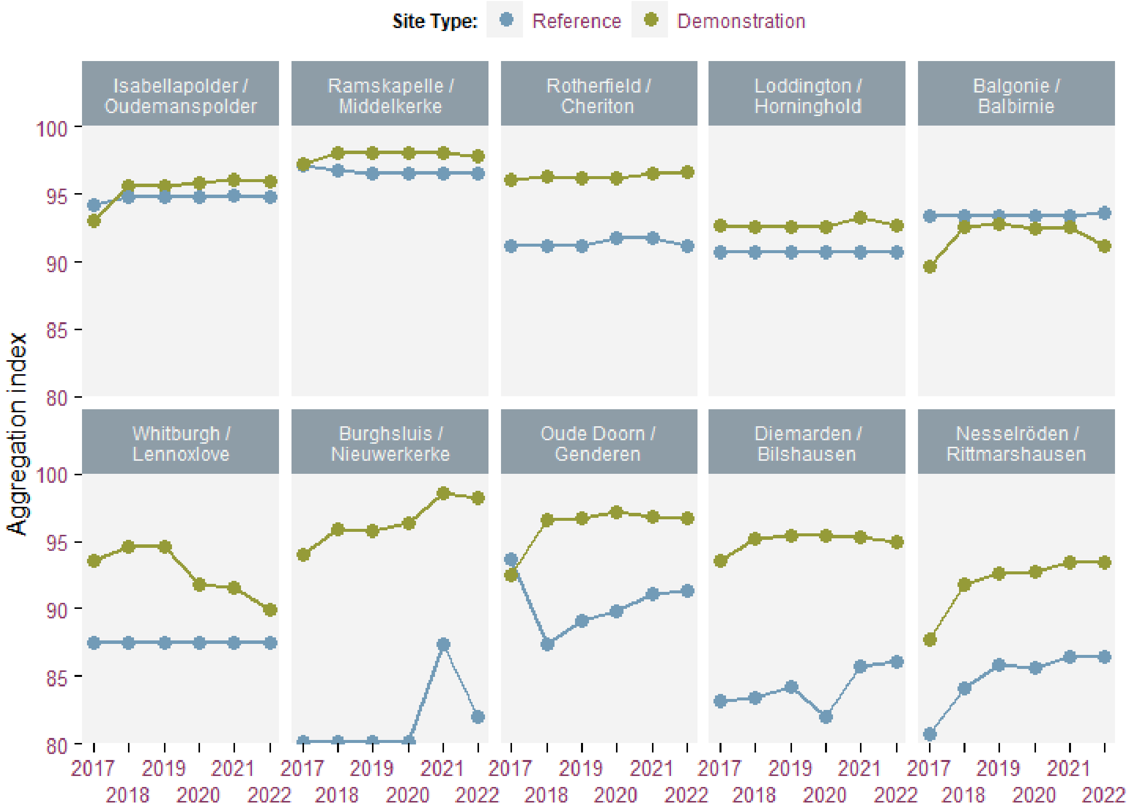


Figure 27: Changes over time in the aggregation index (i.e., the percentage of like-adjacencies) values for nesting habitat at our project sites.

There was no significant interaction between site type and time in the aggregation index of nesting habitat ($F_{(1, 98)}$ = 0.01, p = 0.922, Figure 27). The effect of site type was also not significant ($F_{(1, 9)}$ = 10.16, p = 0.011, Figure 28). The effect of time on the aggregation of nesting habitat was found to be significant overall ($F_{(1, 98)}$ = 14.36, p < 0.001), with aggregation increasing by on average 1.3 across the duration of the project.

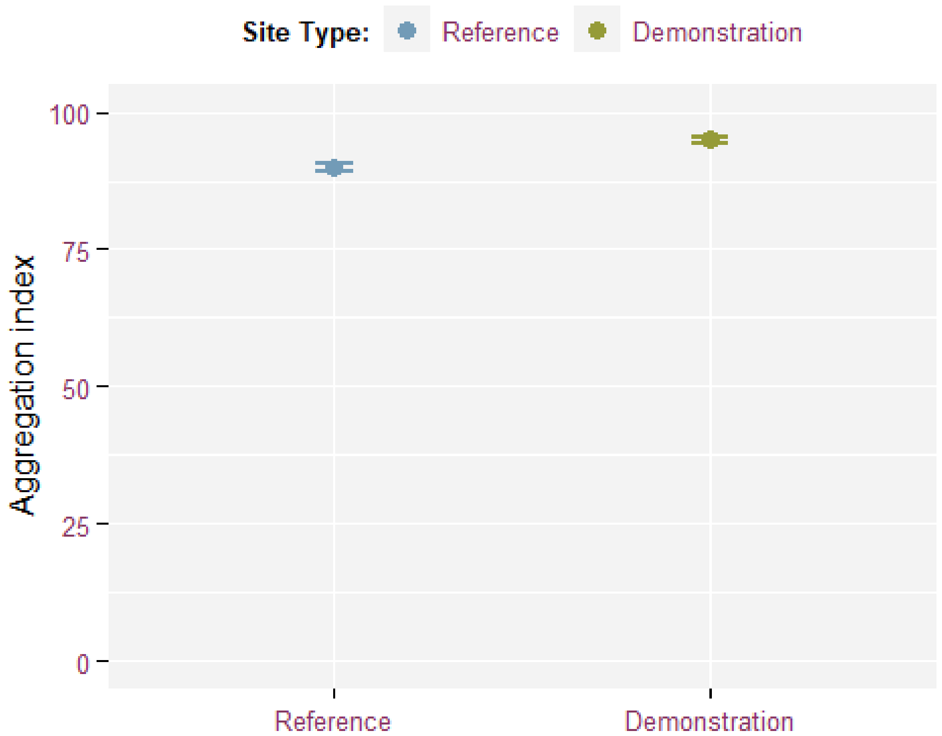


Figure 28: The aggregation index of nesting habitat at our project sites in the final three years of the project (2020 - 2022).

Clumpiness index

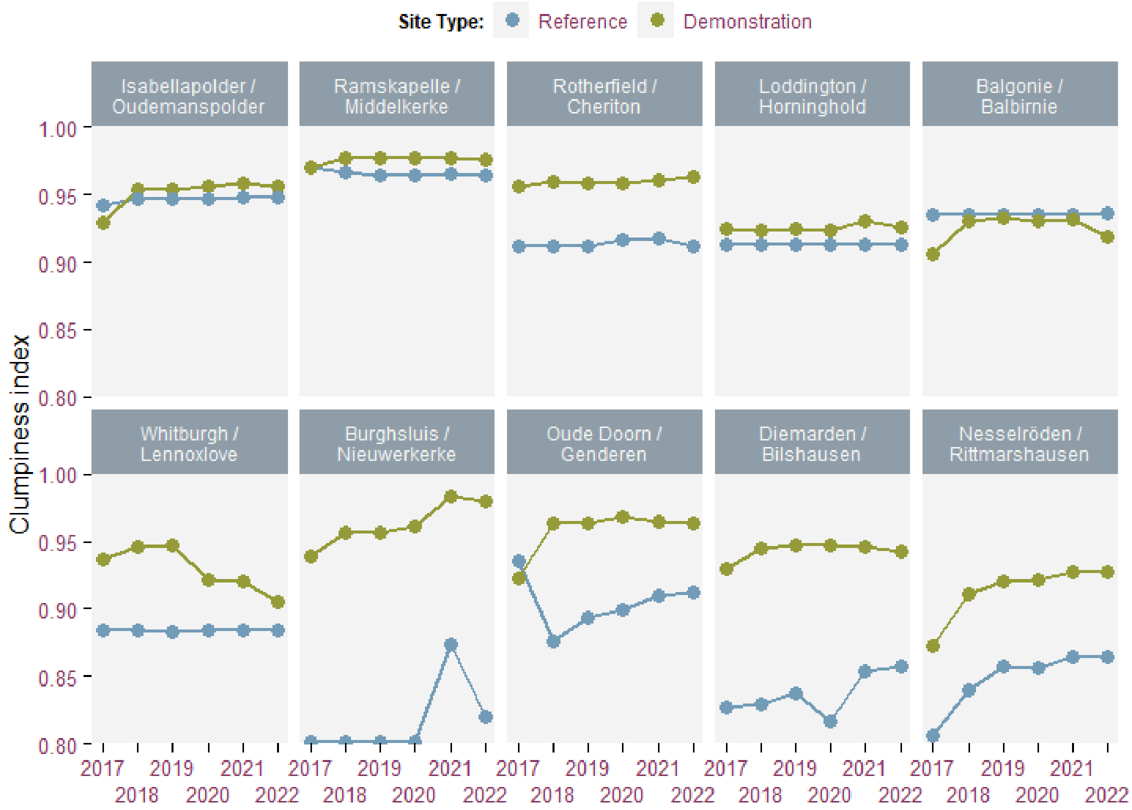


Figure 29: Changes over time in the clumpiness index (i.e., the deviation of like adjacencies from a random distribution of patches) of nesting habitat at our project sites.

The interaction between site type and time was not significant in regard to the clumpiness index of nesting habitat at our project sites ($F_{(1, 98)}$ = 0.02, p = 0.891, Figure 29). Site type was not found to have a significant effect on the clumpiness of these habitats at our project sites ($F_{(1, 9)}$ = 9.37, p = 0.014, Figure 30). The effect of time on the clumpiness of nesting habitat was found to be significant overall ($F_{(1, 98)}$ = 14.86, p < 0.001), with clumpiness increasing by, on average, 0.01 over the course of the project.

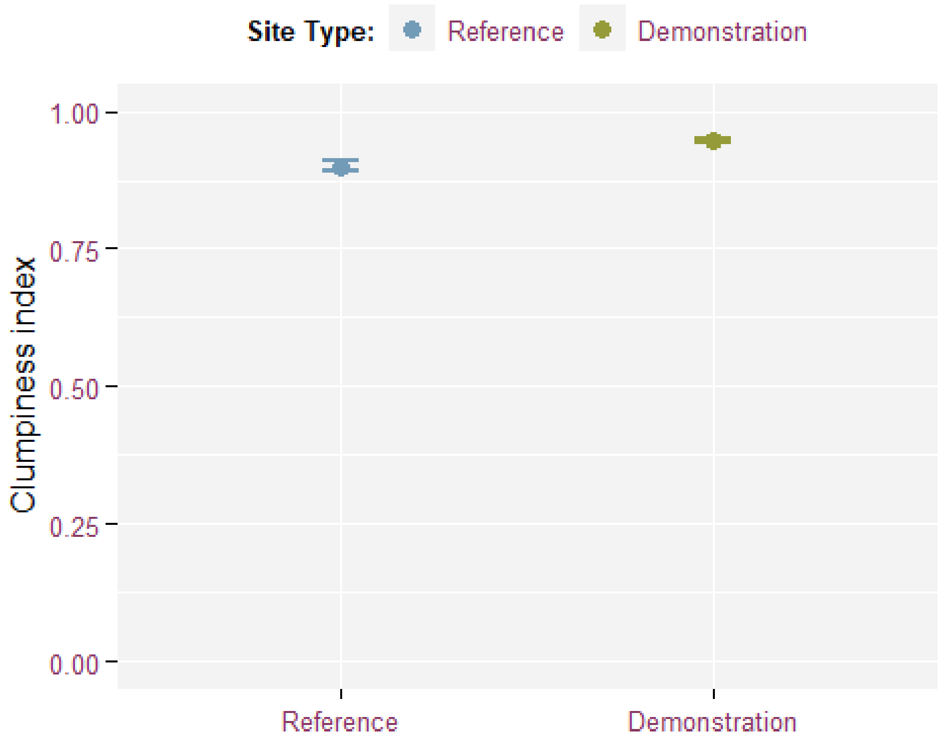


Figure 30: The clumpiness index of nesting habitat at our project sites in the final three years of the project (2020 - 2022).

Normalized landscape shape index

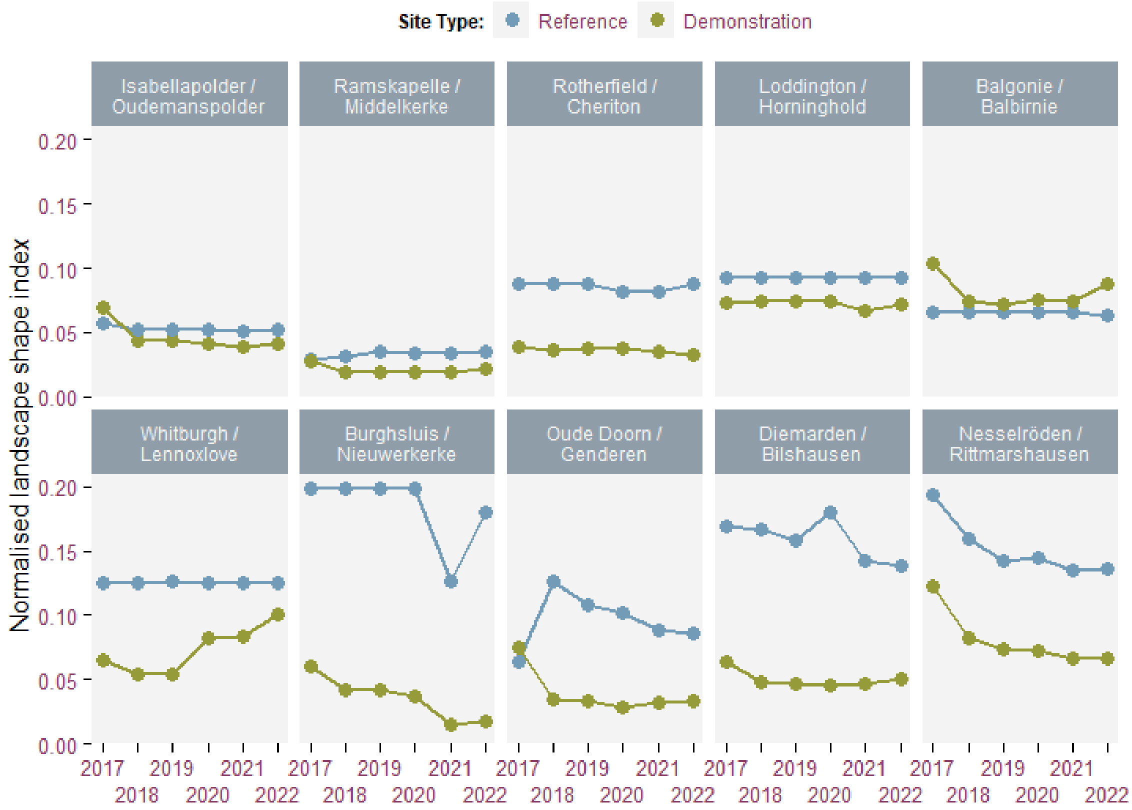


Figure 31: Changes over time in the normalized landscape shape index values of nesting habitat at our project sites.

The interaction between site type and time on the normalised landscape shape index of nesting habitat at our project sites was not significant ($F_{(1, 98)}$ = 5.94, *p* = 0.017, Figure 31). The change in these values over time, however, was found to be significant ($F_{(1, 98)}$ = 14.98, *p* < 0.001) with index values decreasing (i.e., becoming more aggregated) by an average of 0.01 throughout the duration of the project. We found that nesting habitat at our demonstration sites was significantly more aggregated than at our reference sites ($F_{(1, 9)}$ = 13.8, *p* = 0.005), with the average index values at our demonstration sites 50% lower, and therefore more aggregated, than those at our reference sites in the final three years of the project (Figure 32).

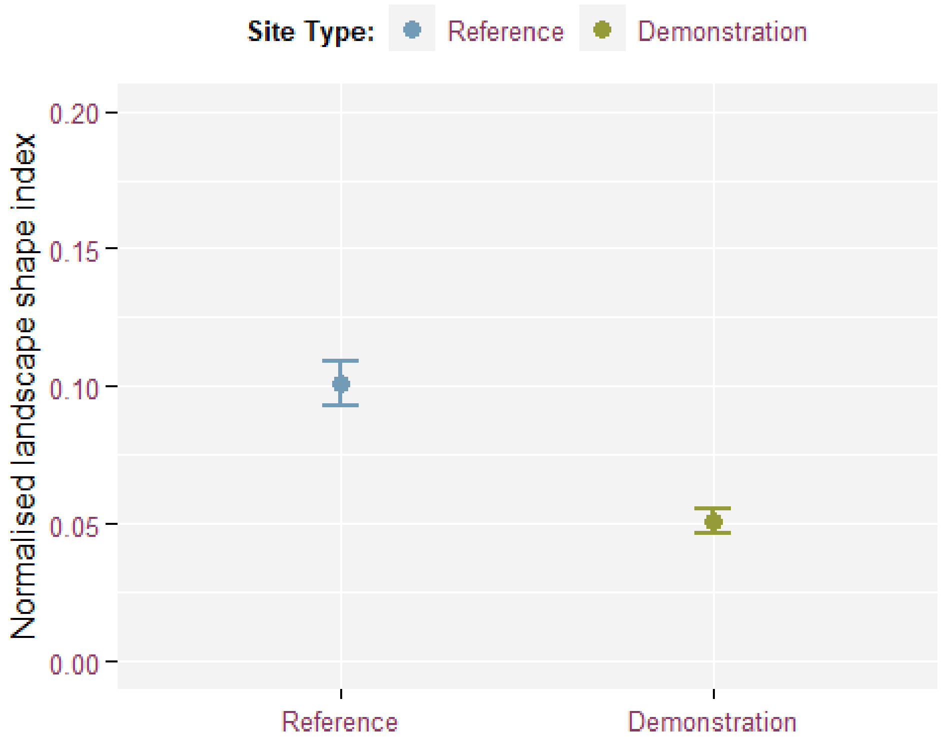


Figure 32: The difference in the normalised landscape shape index of nesting habitat of our project sites in the final three years of the project (2020 - 2022).

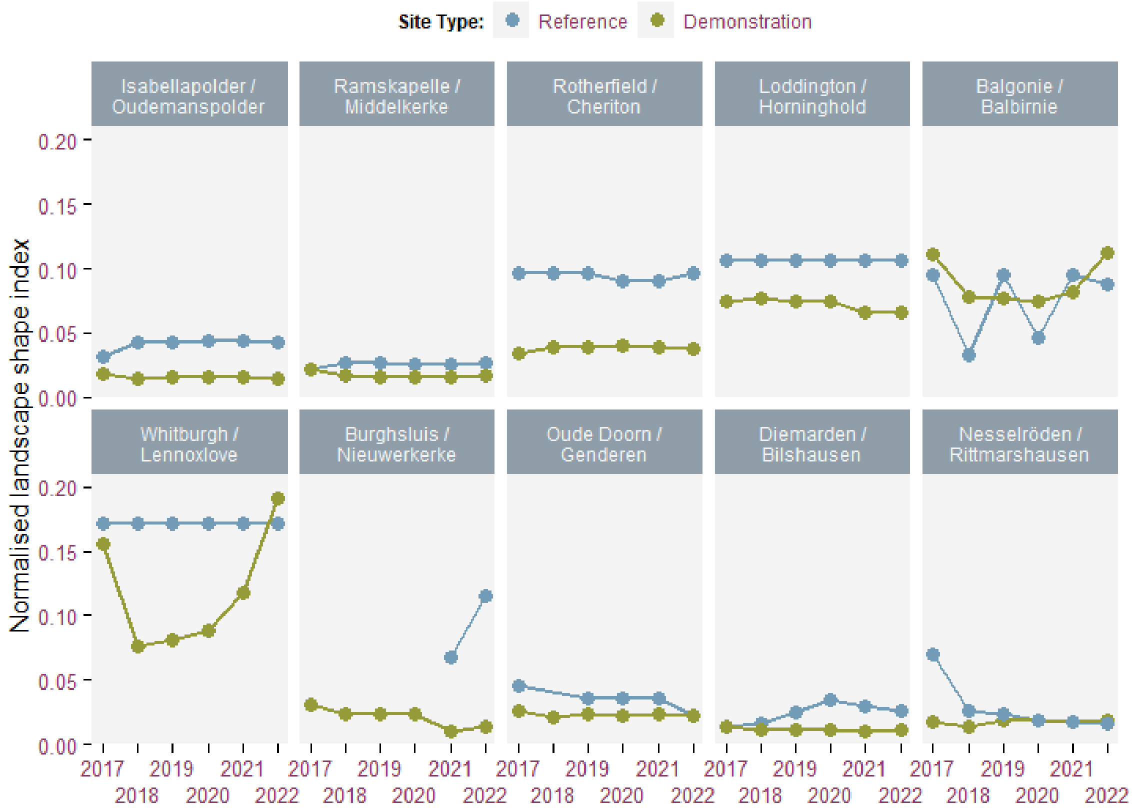


Figure 33: Changes over time in the normalized landscape shape index values of brood-rearing habitat at our project sites.

We did not find a significant interaction between site type and time on the normalised landscape shape index of brood-rearing habitat at our project sites ($F_{(1, 93.4)}$ = 0.39, p = 0.536, Figure 33). We were, however, able to detect a significant difference between values at our demonstration and reference sites ($F_{(1, 9)}$ = 15.93, p = 0.003), with the average index values of our demonstration sites 0.03 (37%) below those of our reference sites (i.e., more aggregated) in the final three years of the project (Figure 34). There was no overall change in the normalized landscape shape index values over the duration of the project ($F_{(1, 93.3)}$ = 0.79, p = 0.375).

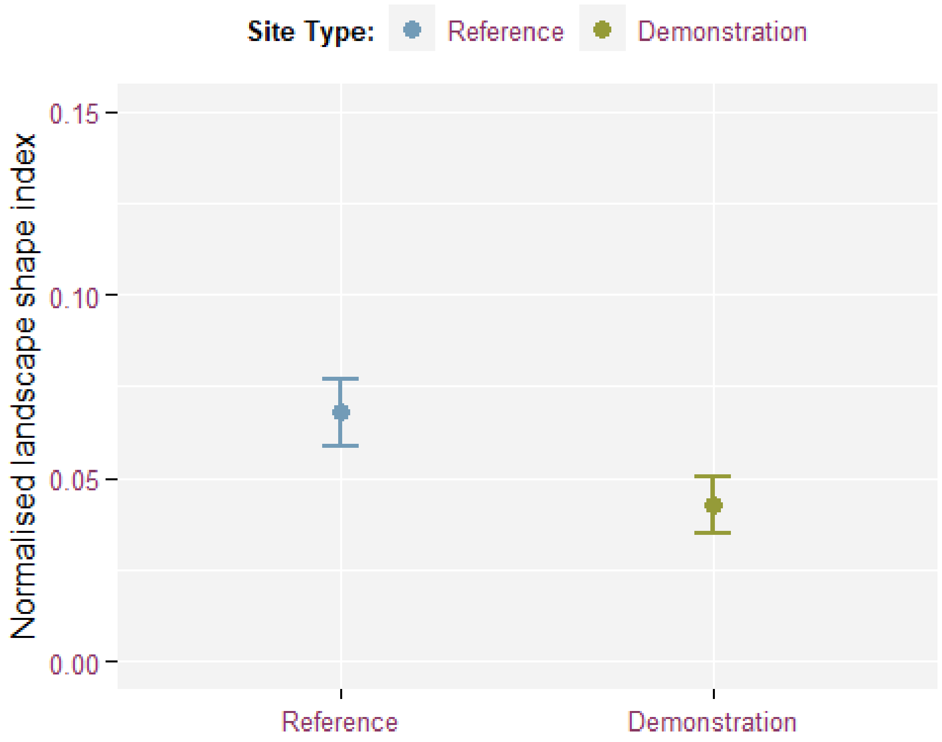


Figure 34: The difference in the normalised landscape shape index of brood-rearing habitat of our project sites in the final three years of the project (2020 - 2022).

Euclidean nearest neighbour distance

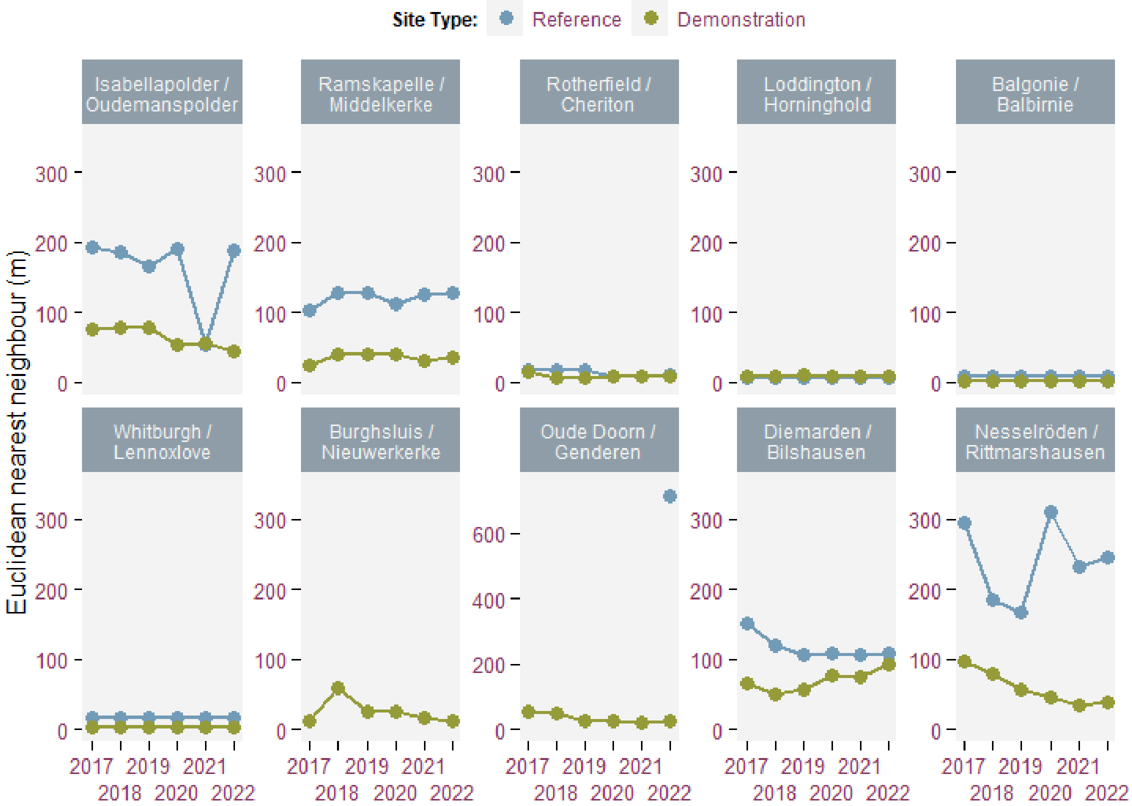


Figure 35: Changes over time in the average Euclidean nearest neighbour distances between brood-rearing habitat at our project sites – note that y axis scales are not consistent between sites.

There was no significant interaction between site type and time when considering the average Euclidean nearest neighbour distance between brood-rearing habitats at our project sites ($F_{(1, 88)} = 0.69$, $p = 0.408$, Figure 35). We were, however, able to detect that site type had a significant effect on the distance between brood-rearing habitat ($F_{(1, 8)} = 12.01$, $p = 0.008$), with the average distance between brood-rearing habitats at our demonstration sites 80 meters shorter than at our reference sites in the final three years of the project (Figure 36). We also detected that these values changed significantly over time ($F_{(1, 87.9)} = 9.42$, $p = 0.003$), with average distances between brood-rearing habitats overall increasing by, on average 53 meters throughout the course of the project,

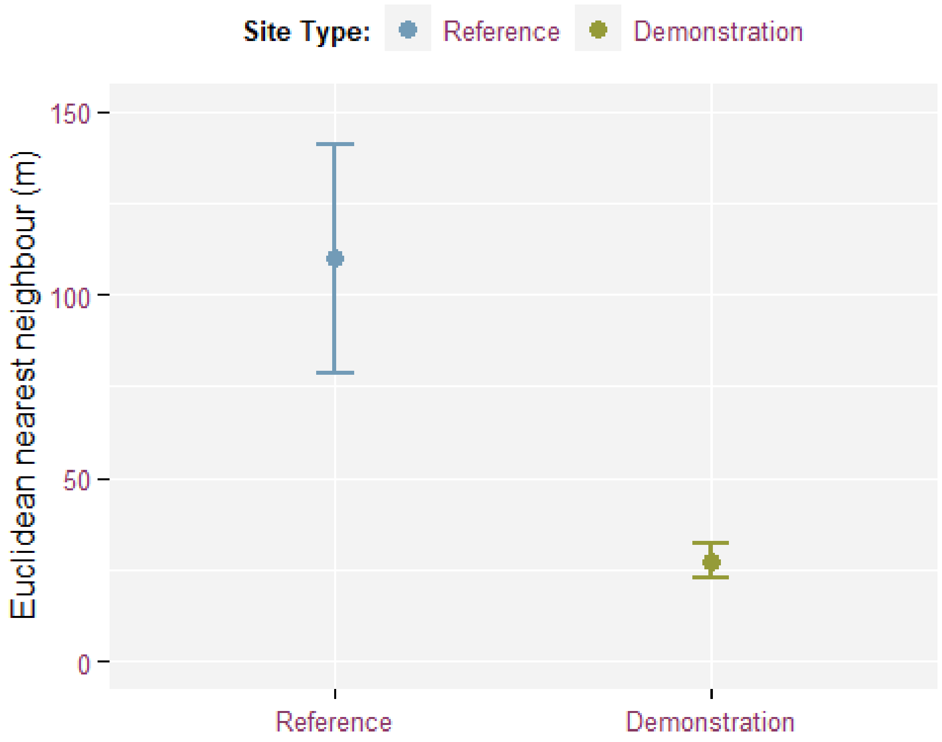


Figure 36: The difference in the Euclidean nearest neighbour distance of brood-rearing habitat at our project sites in the final three years of the project (2020 - 2022).

Distance between nesting and brood-rearing habitat

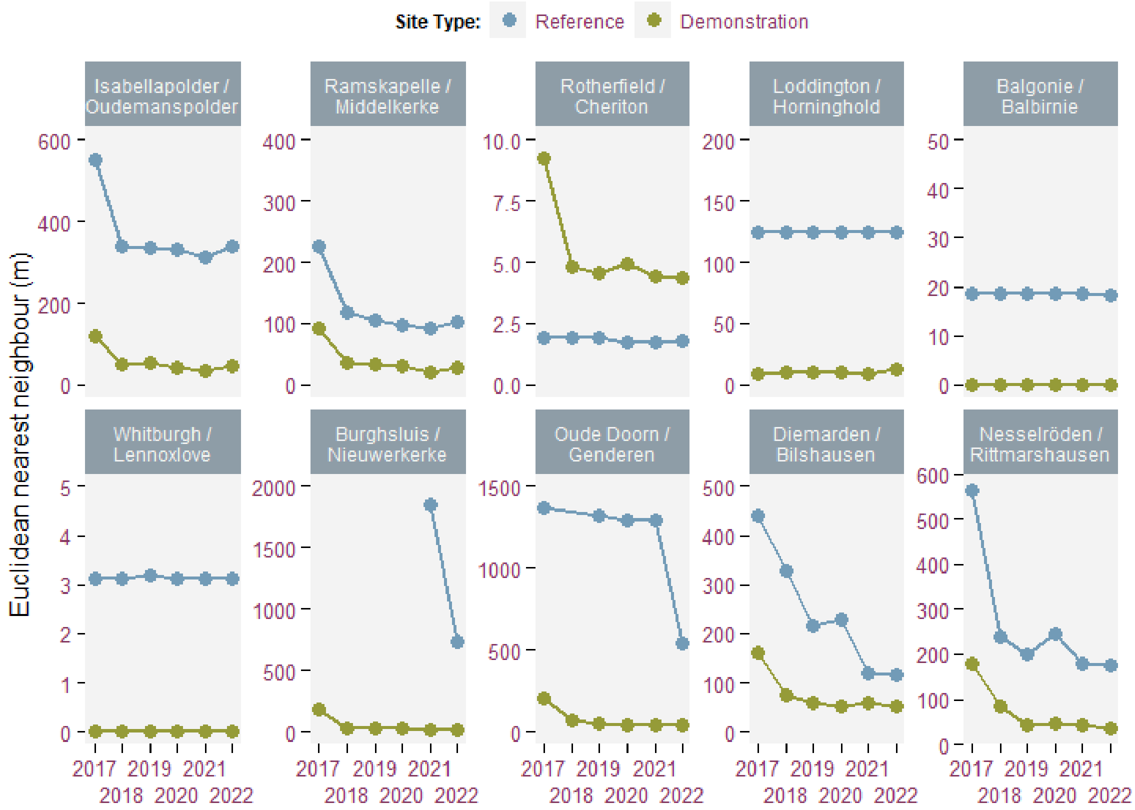


Figure 37: Changes over time in the average Euclidean nearest neighbour distances between nesting and brood-rearing habitat at our project sites – note that y axis scales are not consistent between sites.

We did not detect a significant interaction between site type and time when investigating the average distance from patches of nesting habitat to the nearest brood-rearing habitat ($F_{(1, 98)}$ = 3.91, *p* = 0.051, Figure 37). The effect of site type on the distance between these habitats was significant ($F_{(1, 9)}$ = 13.68, *p* = 0.005), with the average distance on our demonstration sites between these two types of habitats in the final three years of the project being 10 times smaller than those at reference sites within the same period (Figure 38). We also found that time had a significant effect on the distance between these habitats overall ($F_{(1, 98)}$ = 52.17, *p* < 0.001), with the average distance between these habitats decreasing by 58% over the course of the project.

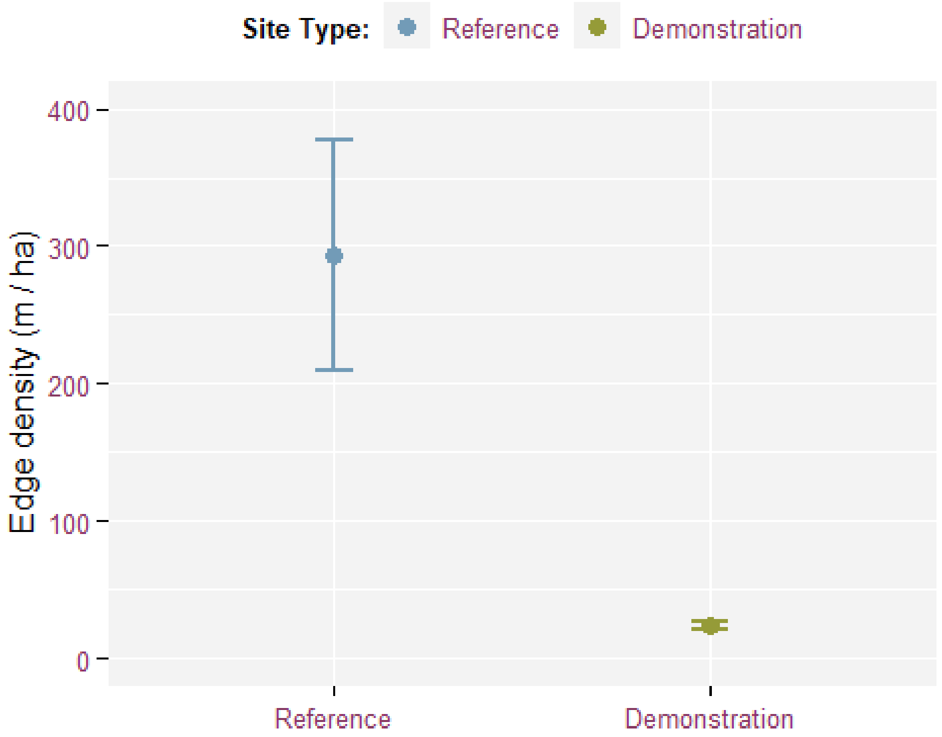


Figure 38: The Euclidean nearest neighbour distance between nesting and brood-rearing habitat of our project sites in the final three years of the project (2020 - 2022).

Edge density

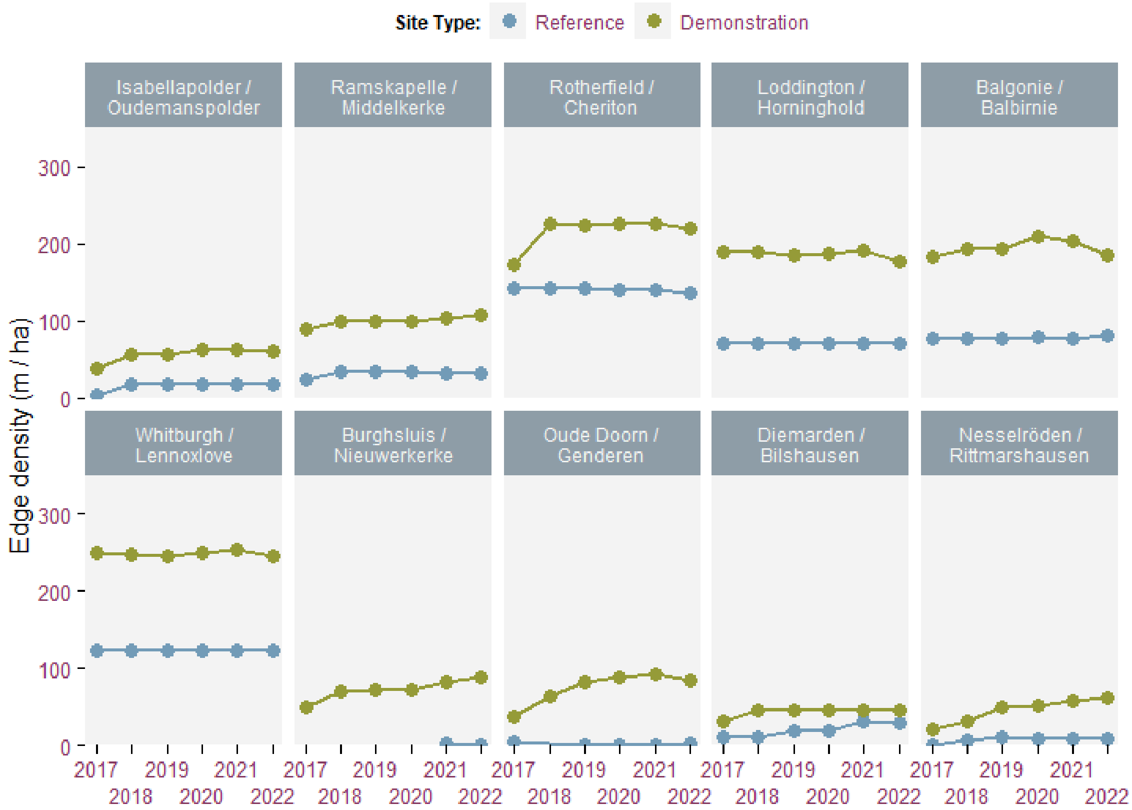


Figure 39: Changes over time in the edge density of brood-rearing habitat at our project sites.

We were unable to detect a significant interaction between site type and time in regard to the edge density of brood-rearing habitat at our project sites ($F_{(1, 98)}$ = 0.05, p = 0.817, Figure 39). The effect of site type on edge density, however, was significant ($F_{(1, 8.9)}$ = 14.75, p = 0.004), with the average length of habitat edge per hectare at our demonstration sites 77.5 meters greater than at our reference sites in the final three years of the project (Figure 40). These values overall, also, changed significantly through time ($F_{(1, 93)}$ = 13.92, p < 0.001), increasing by an average of 12.9 m throughout the duration of the project.

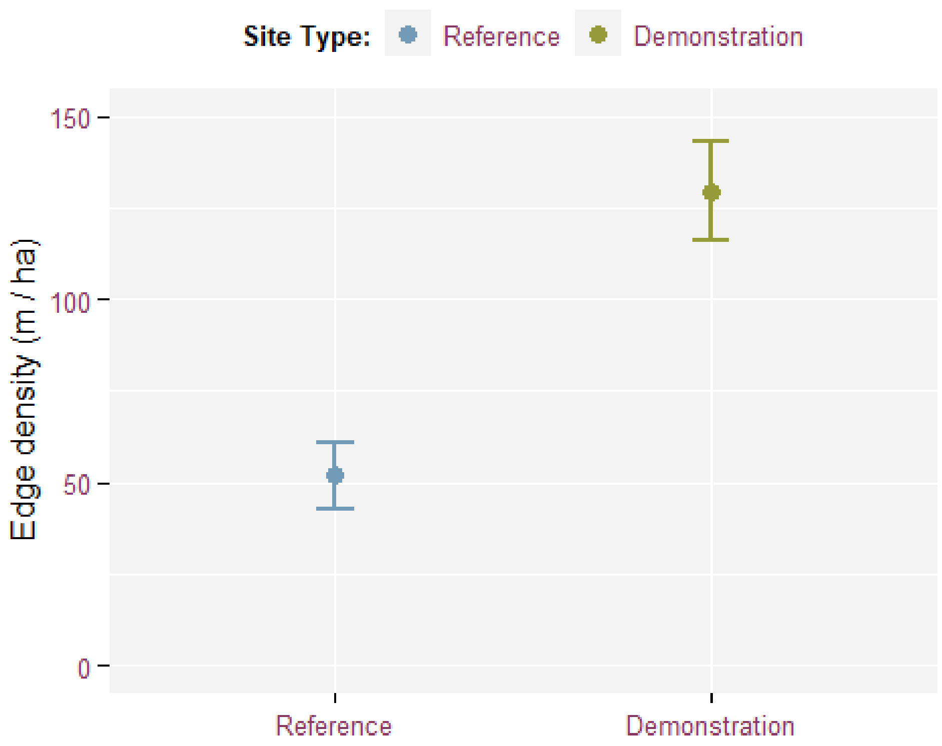


Figure 40: The edge density of brood-rearing habitat of our project sites in the final three years of the project (2020 - 2022).

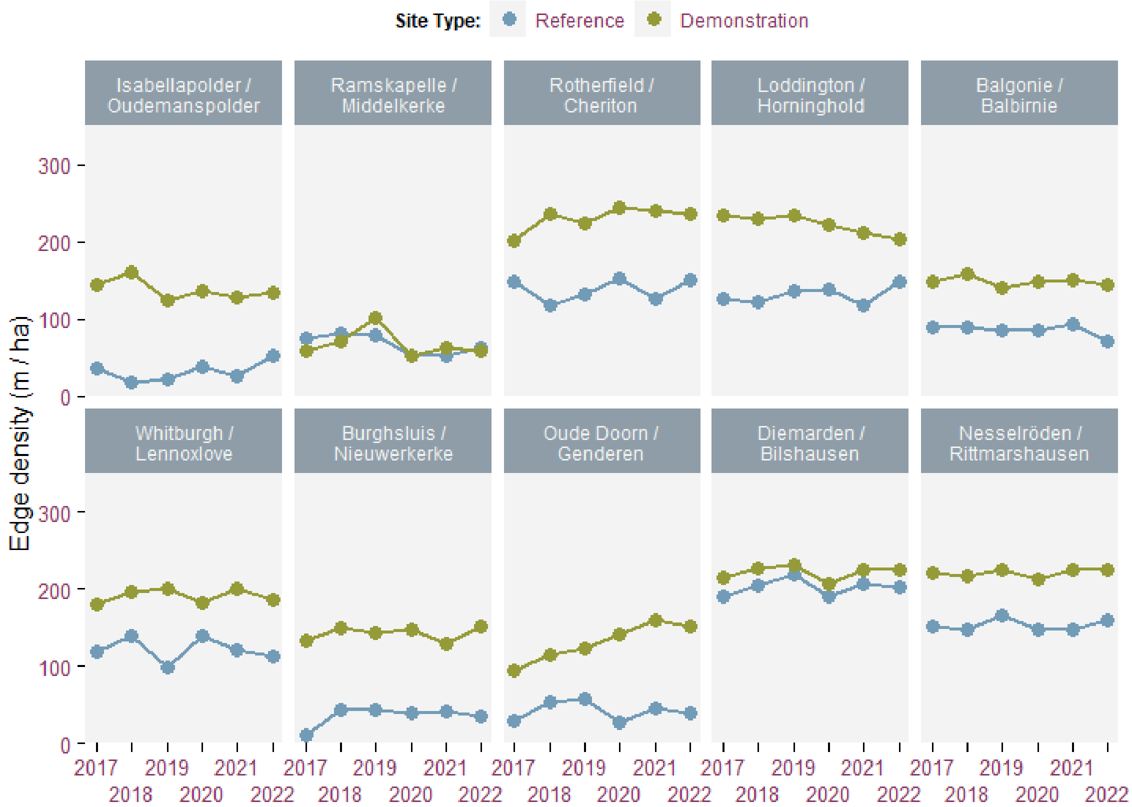


Figure 41: Changes over time of the edge density of overwinter cover habitat at our project sites.

As with the other habitat types we considered for this metric, we were unable to detect a significant interaction between time and site type on the edge density of overwinter cover habitat at our project sites ($F_{(1, 98)}$ = 0.42, *p* = 0.521, Figure 41). Site type was found to have a significant effect on edge density ($F_{(1, 9)}$ = 15.27, *p* = 0.004), with the average amount of habitat edge per hectare at our demonstration sites 71.0 meters greater than at our reference sites in the final three years of the project (Figure 42). These values did not, however, change significantly through time ($F_{(1, 98)}$ = 1.26, *p* = 0.264).

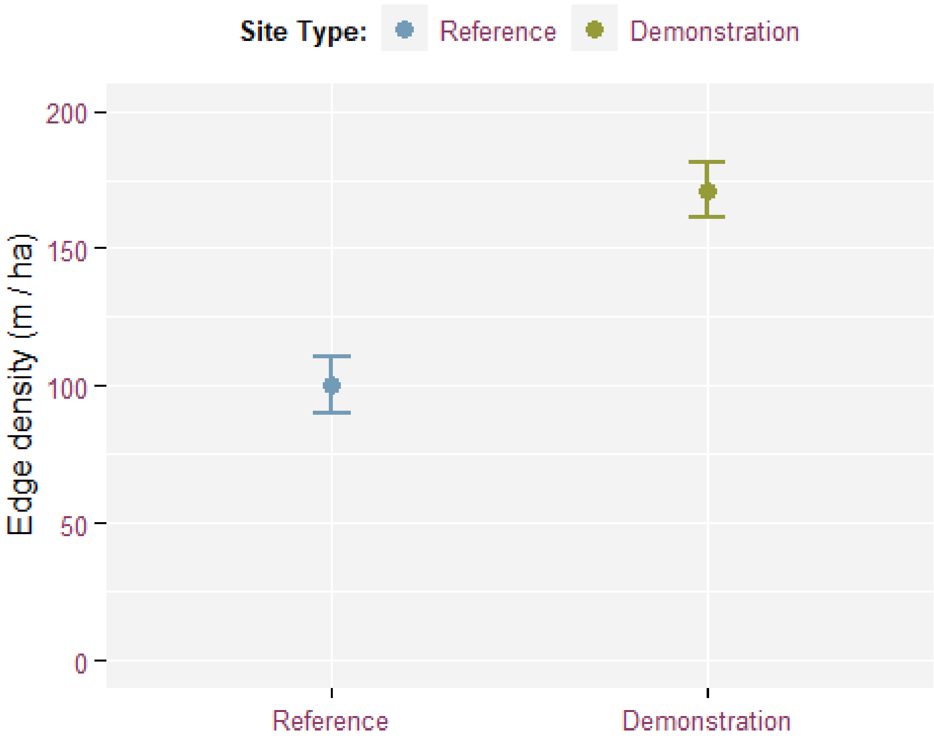


Figure 42: The edge density of overwinter cover habitat of our project sites in the final three years of the project (2020 - 2022).

Mean contiguity index

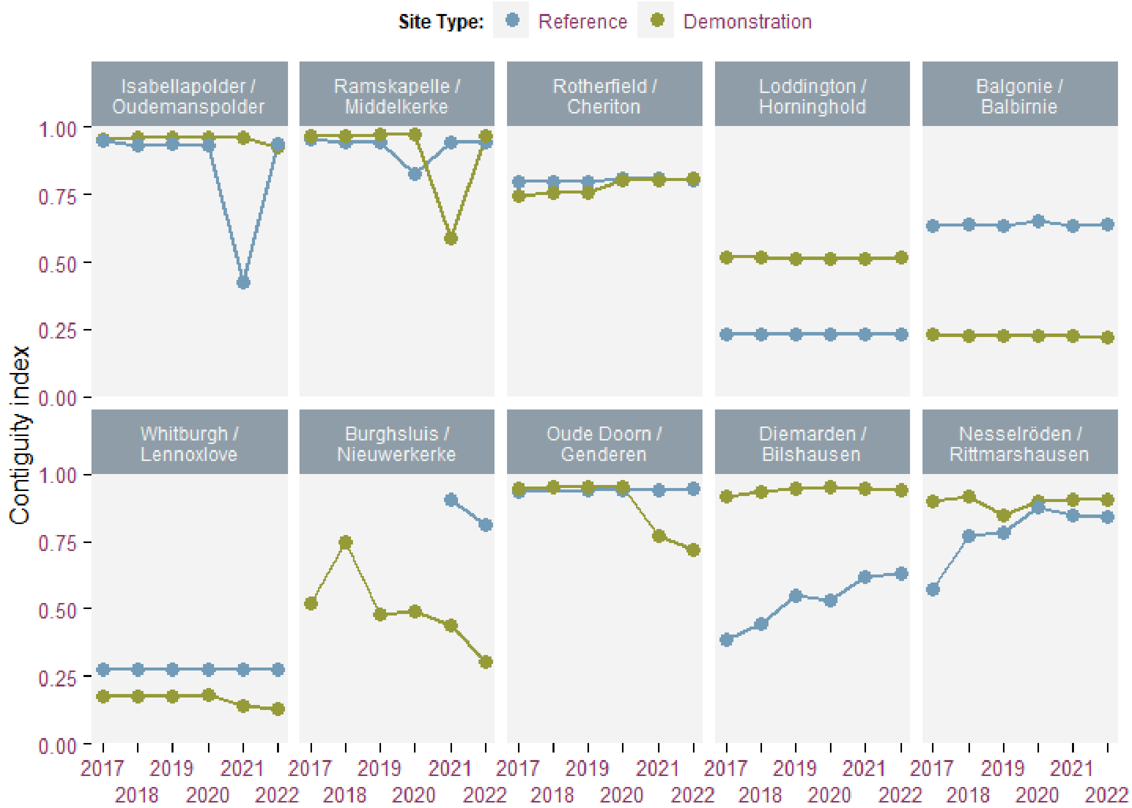


Figure 43: Changes over time of the contiguity index values for brood-rearing habitat at our project sites.

We detected a significant interaction between site type and time when investigating the contiguity of brood-rearing habitat at our project sites ($F_{(1, 93.2)}$ = 6.94, p = 0.010, Figure 43). Values at our demonstration site significantly decreased ($F_{(1, 49)}$ = 8.81, p = 0.005), decreasing by 10% from its peak in 2018, whilst values at our reference sites did not significantly change ($F_{(1, 44.2)}$ = 0.89, p = 0.349).

Patch-level metrics

Semi-natural habitat size

Mean polygon area

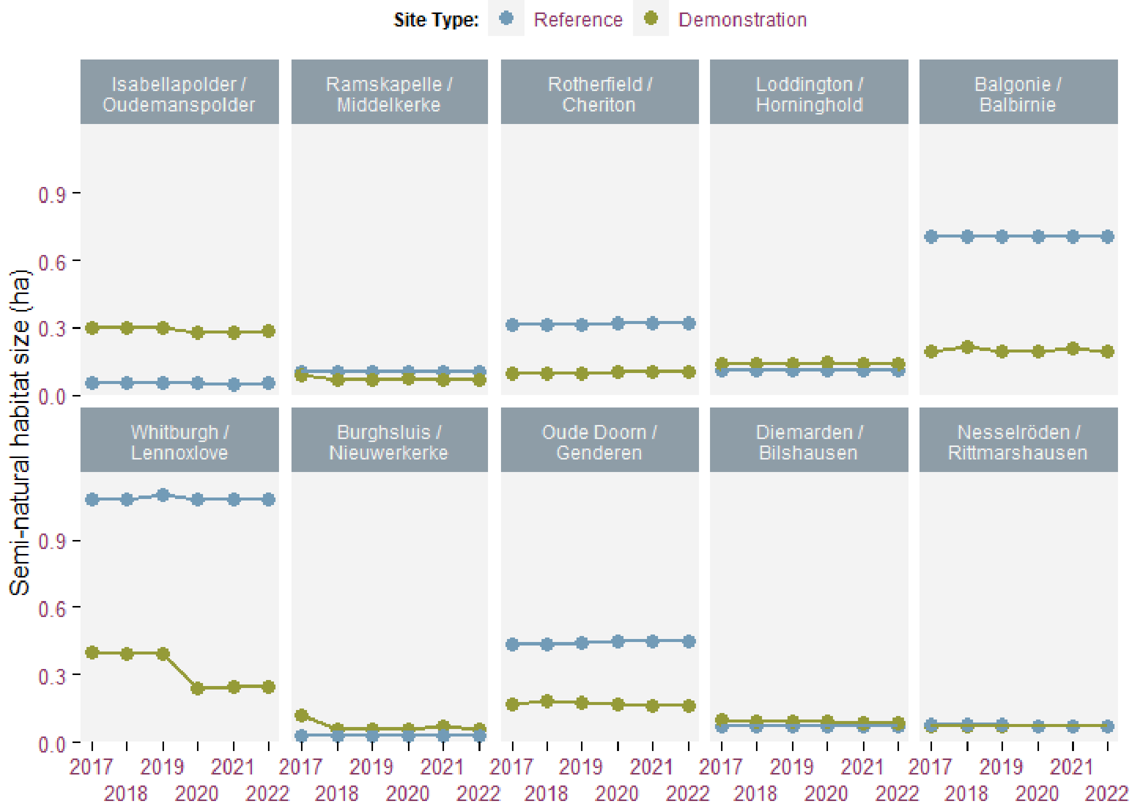


Figure 44: Differences in average semi-natural habitat polygon sizes over time.

We found a significant interaction between site type and year on the size of semi-natural habitat polygons at our project sites ($F_{(1, 98)} = 8.03$, $p = 0.006$), with values at our demonstration sites significantly decreasing ($F_{(1, 49)} = 10.67$, $p = 0.002$) by 0.03 ha (or 16% over the duration of the project) and such little variation at our reference sites that our models were unable to converge.

Mean patch area

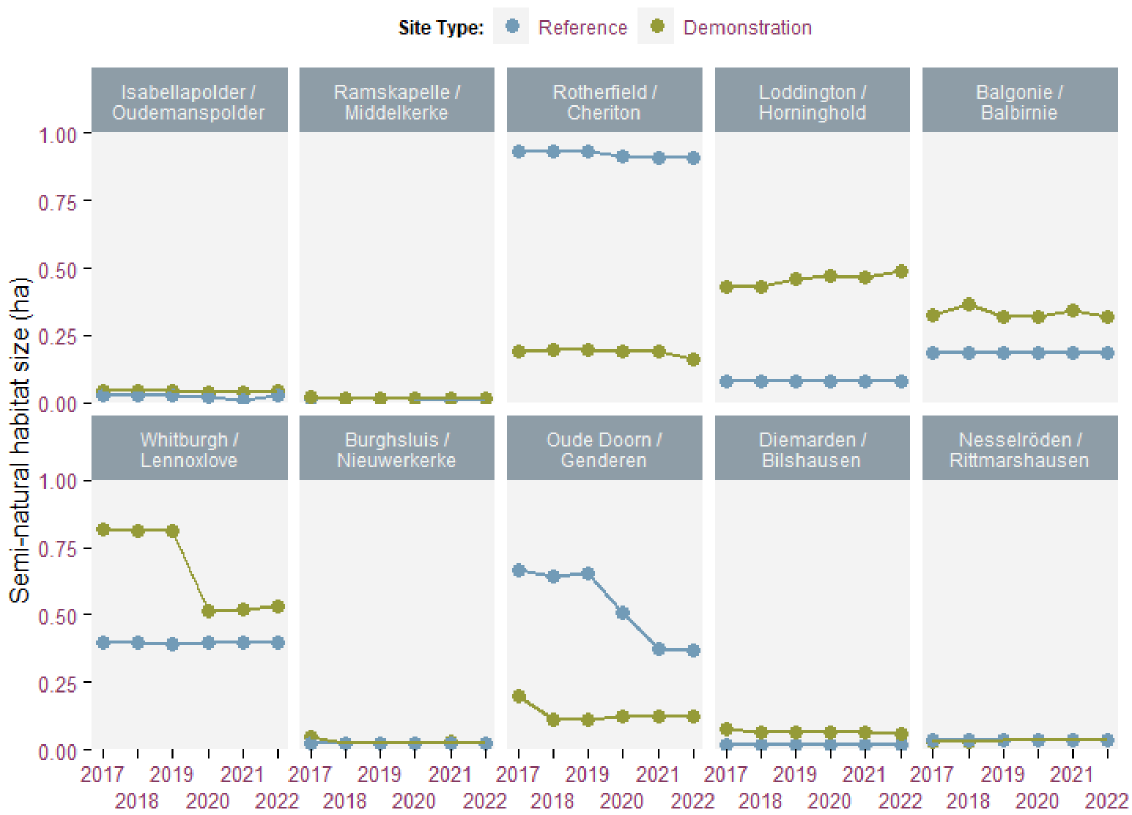


Figure 45: Average semi-natural habitat patch sizes over time.

When investigating the average size of semi-natural habitat patches at our project sites we were unable to find a significant interaction between site type and time ($F_{(1, 98)}$ = 0.72, p = 0.399, Figure 45). Site type, likewise, was also not found to have a significant effect ($F_{(1, 9)}$ = 0.32, p = 0.588). The average size of these habitats was found to have changed significantly through time ($F_{(1, 98)}$ = 15.42, p < 0.001), with the patch size decreasing by, on average, 0.03 ha over the course of the project.

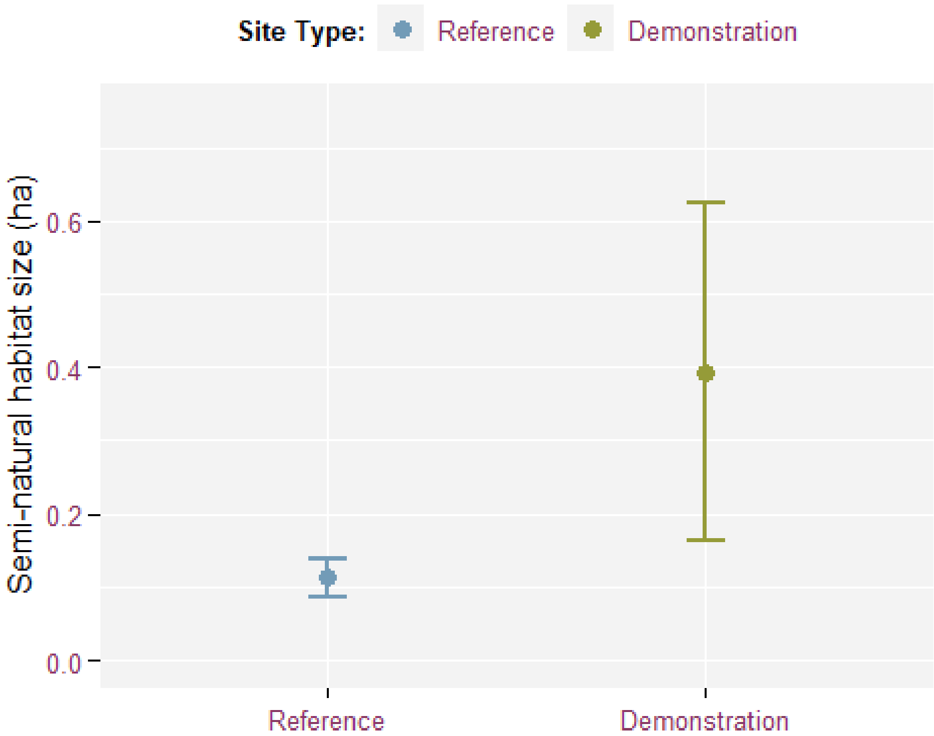


Figure 46: The patch sizes of semi-natural habitat on our project sites in the final three years of the project (2020 - 2022).

Beneficial habitat size

Mean polygon area

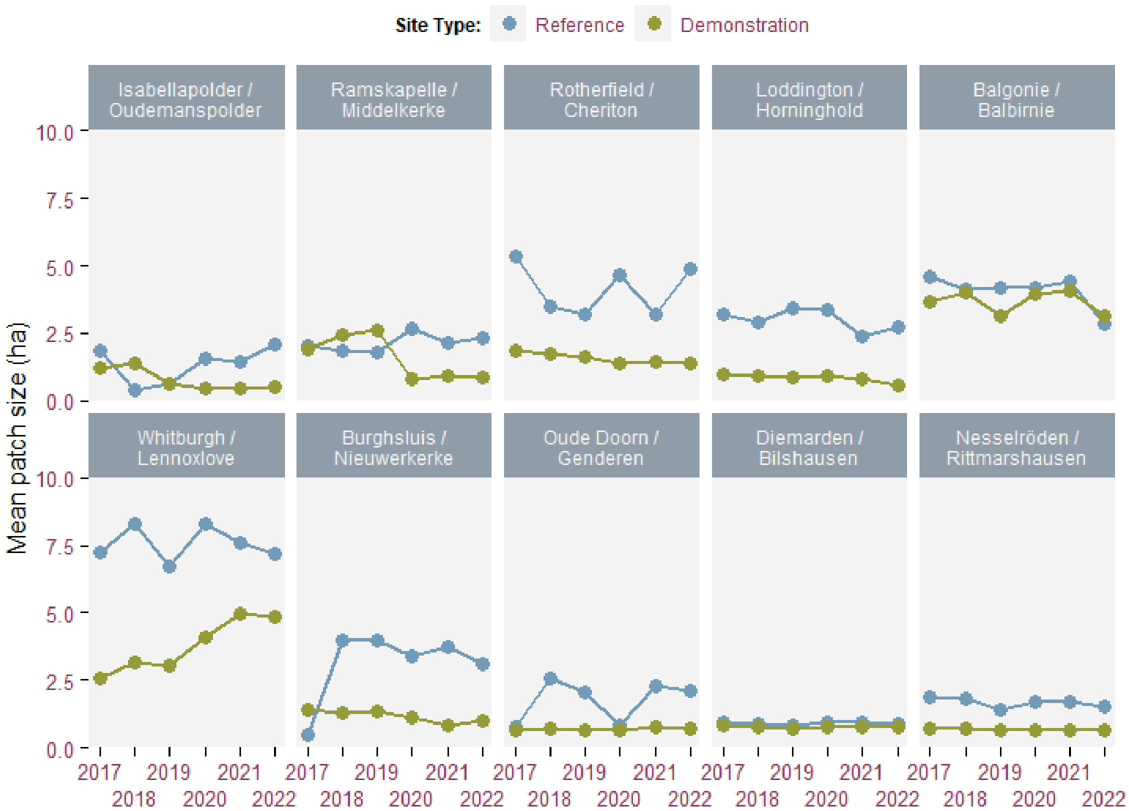


Figure 47: Changes over time of the mean polygon size in hectares of overwinter cover habitat at our project sites.

We were able to detect a significant interaction between site type and time in the average area of overwinter cover habitat polygons ($F_{(1, 98)}$ = 7.86, p = 0.006, Figure 47). We found that values at our demonstration sites significantly decreased by 0.27 ha over the duration of the project ($F_{(1, 49)}$ = 9.05, p = 0.004), whilst values at our reference sites did not change significantly ($F_{(1, 49)}$ = 1.95, p = 0.169).

Mean shape index

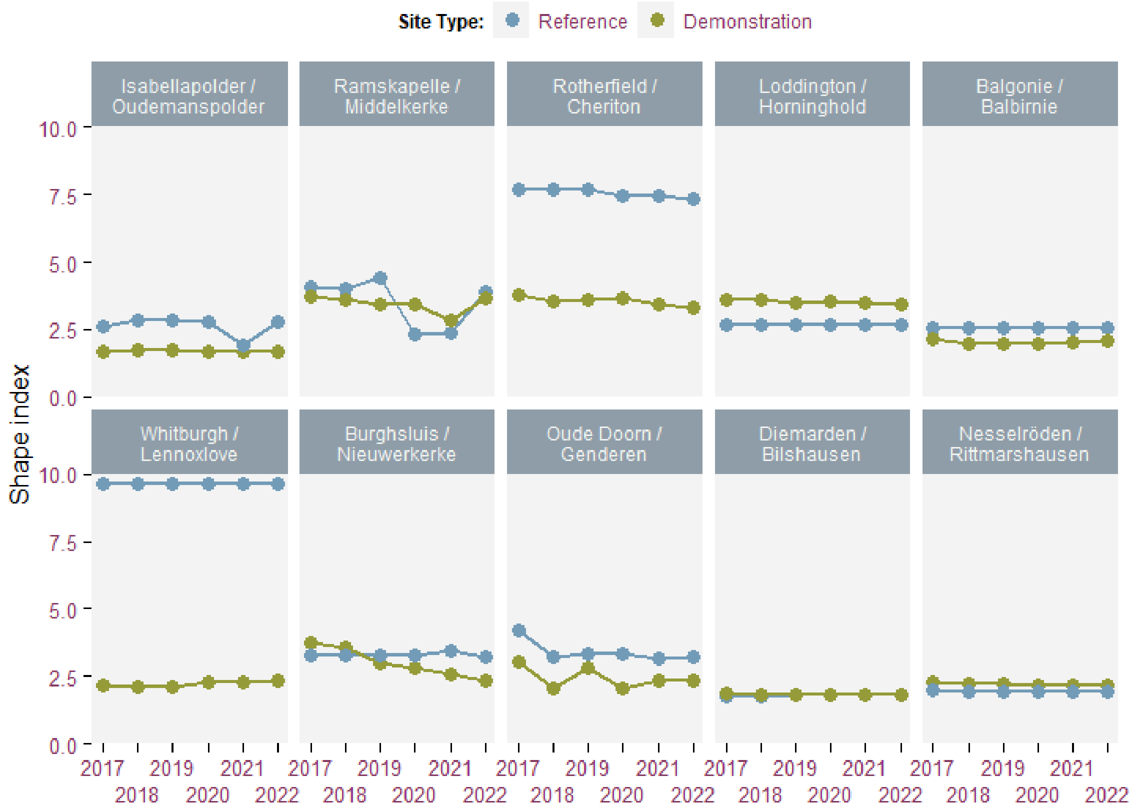


Figure 48: Changes over time in the mean shape index values of nesting habitat at our project sites.

We were unable to detect a significant interaction between site type and time on the mean shape index of nesting habitat patches at our project sites ($F_{(1, 98)}$ = 0.20, p = 0.658, Figure 48). We also did not detect a significant effect of site type on the mean shape index of nesting habitat ($F_{(1, 9)}$ = 3.31, p = 0.102). These values, however, were found to have changed significantly over time ($F_{(1, 98)}$ = 10.63, p = 0.002), with index values overall decreasing by, on average, 0.2 over the duration of the project.

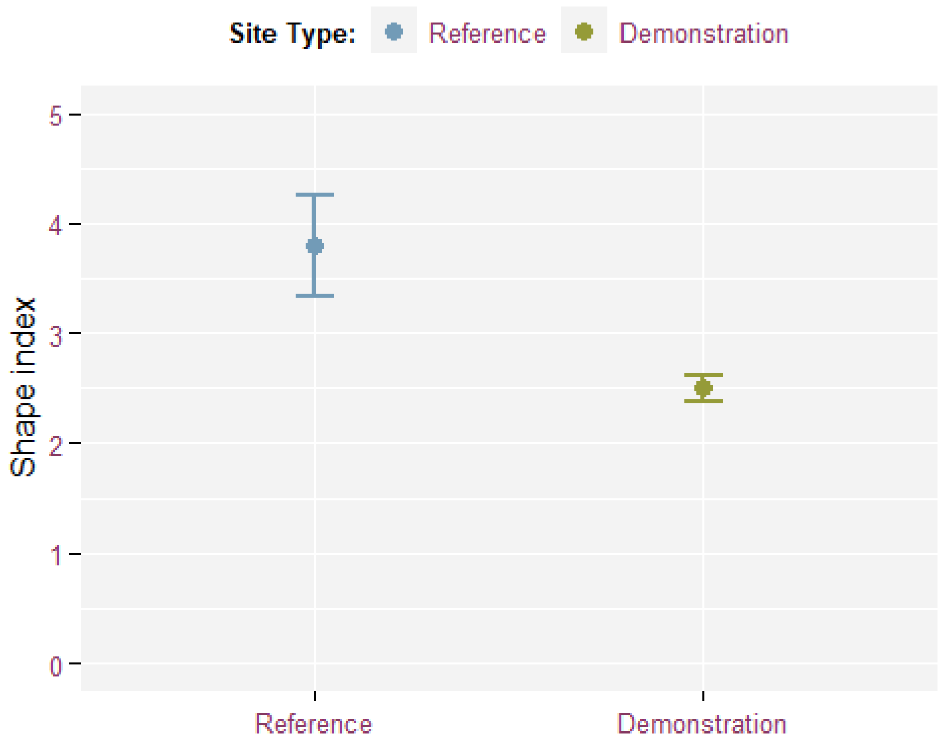


Figure 49: The average shape index of nesting habitat of our project sites in the final three years of the project (2020 - 2022).

Mean fractal dimension index

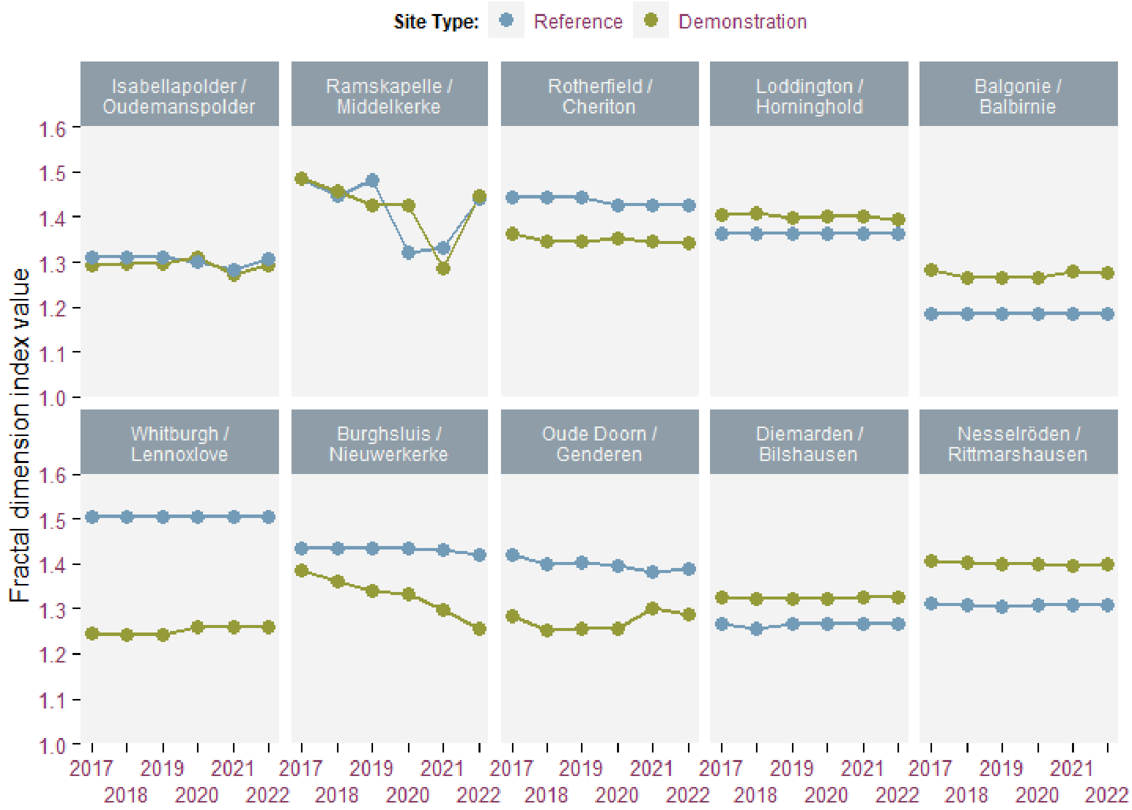


Figure 50: Changes over time in the fractal dimension index values of nesting habitat at our project sites.

We were unable to find a significant interaction between time and site type when investigating the mean fractal dimension index of nesting habitat at our project sites ($F_{(1, 98)}$ = 0.10, p = 0.758, Figure 50). In addition, we were unable to detect a significant difference between the fractal dimension index of nesting habitat at our demonstration and reference sites ($F_{(1, 9)}$ = 0.62, p = 0.450, Figure 51). Values, however, were found to have changed significantly over time ($F_{(1, 98)}$ = 8.32, p = 0.005), with index values overall decreasing by, on average, 0.02 over the duration of the project.

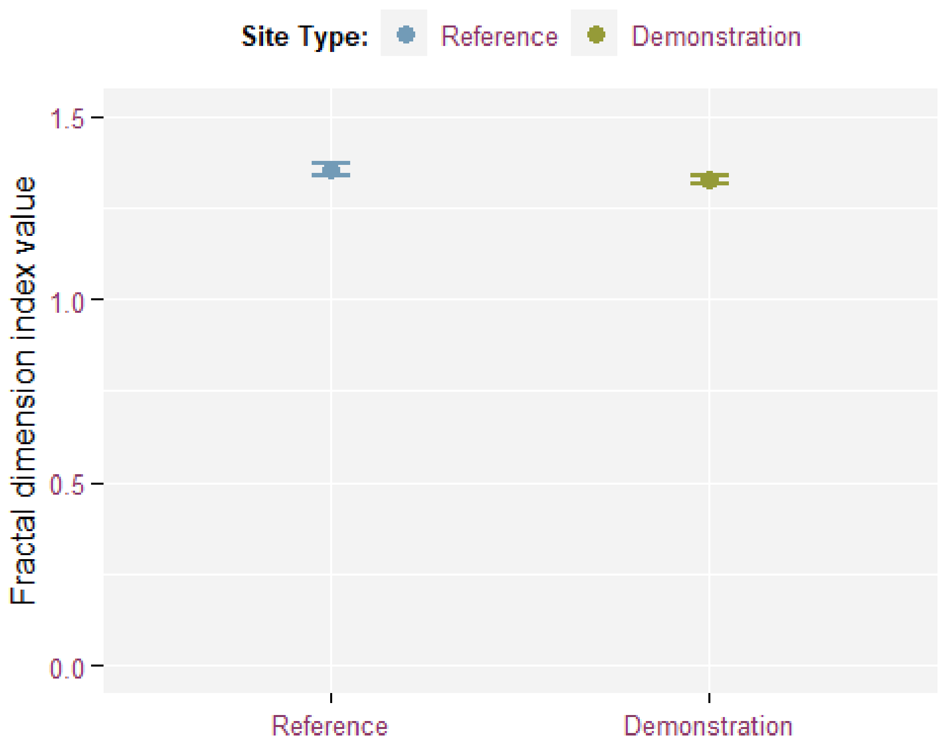


Figure 51: The difference in the average fractal dimension index of nesting habitat of our project sites in the final three years of the project (2020 - 2022).

Core area index

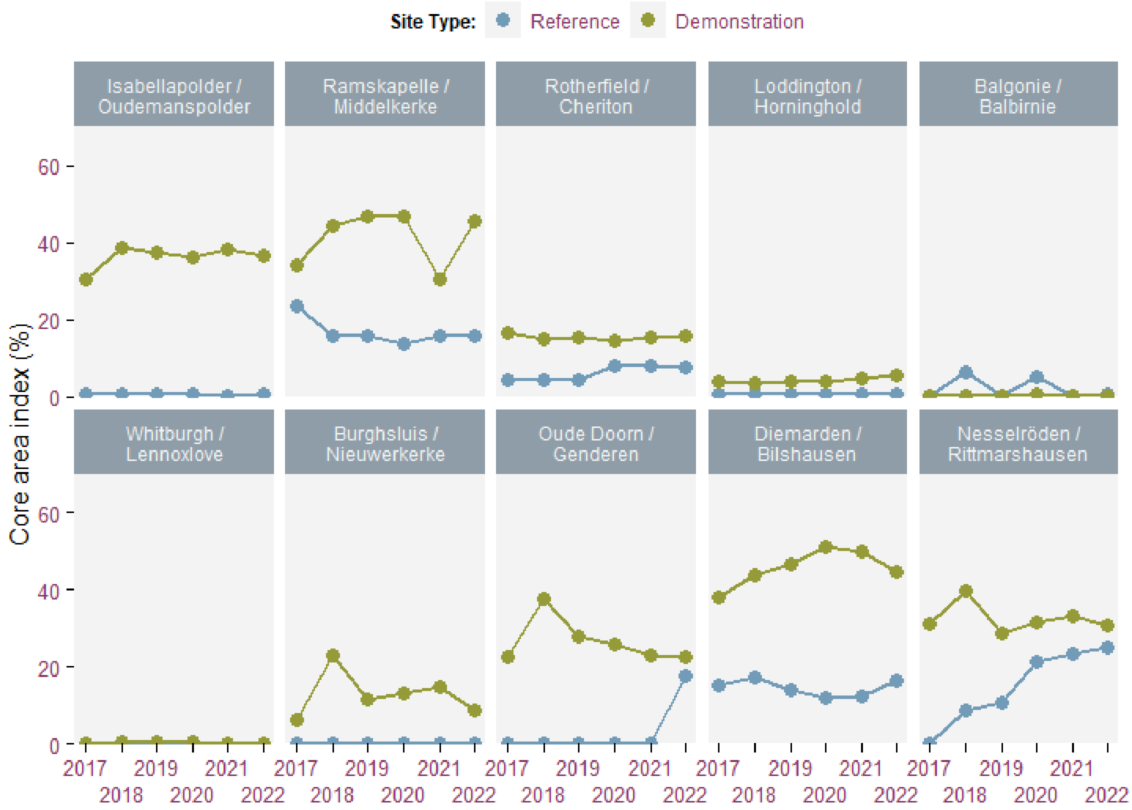


Figure 52: Changes over time in the core area index values of brood-rearing habitat at our project sites – note that Whitburgh and Lennoxlove values overlap.

We were unable to detect a significant interaction between time and site type on the core area index values of brood-rearing habitat at our project sites ($F_{(1, 98)}$ = 3.00, p = 0.087, Figure 52). We did, however, find that the effect of site type on these values was significant ($F_{(1, 9)}$ = 16.99, p = 0.003), with the average index values of our demonstration sites found to be 14.6 higher than those of our reference sites in the final three years of the project (Figure 53). We did not, however, detect that these values changed significantly over the course of the project ($F_{(1, 98)}$ = 4.39, p = 0.039).

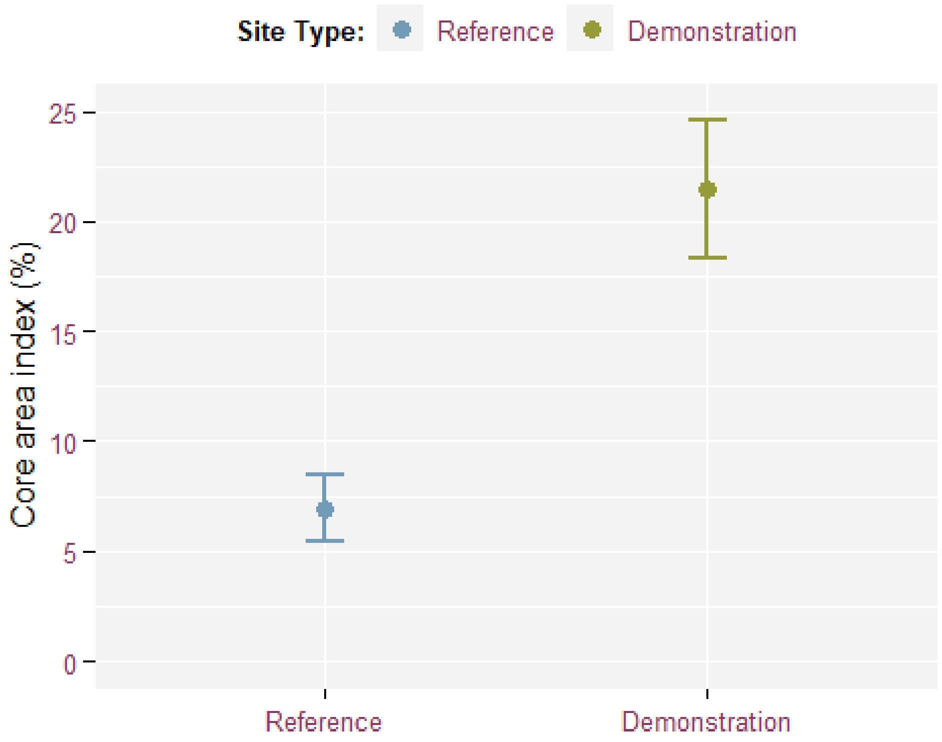


Figure 53: The core area index of brood-rearing habitat of our project sites in the final three years of the project (2020 - 2022).

Core area percentage of landscape

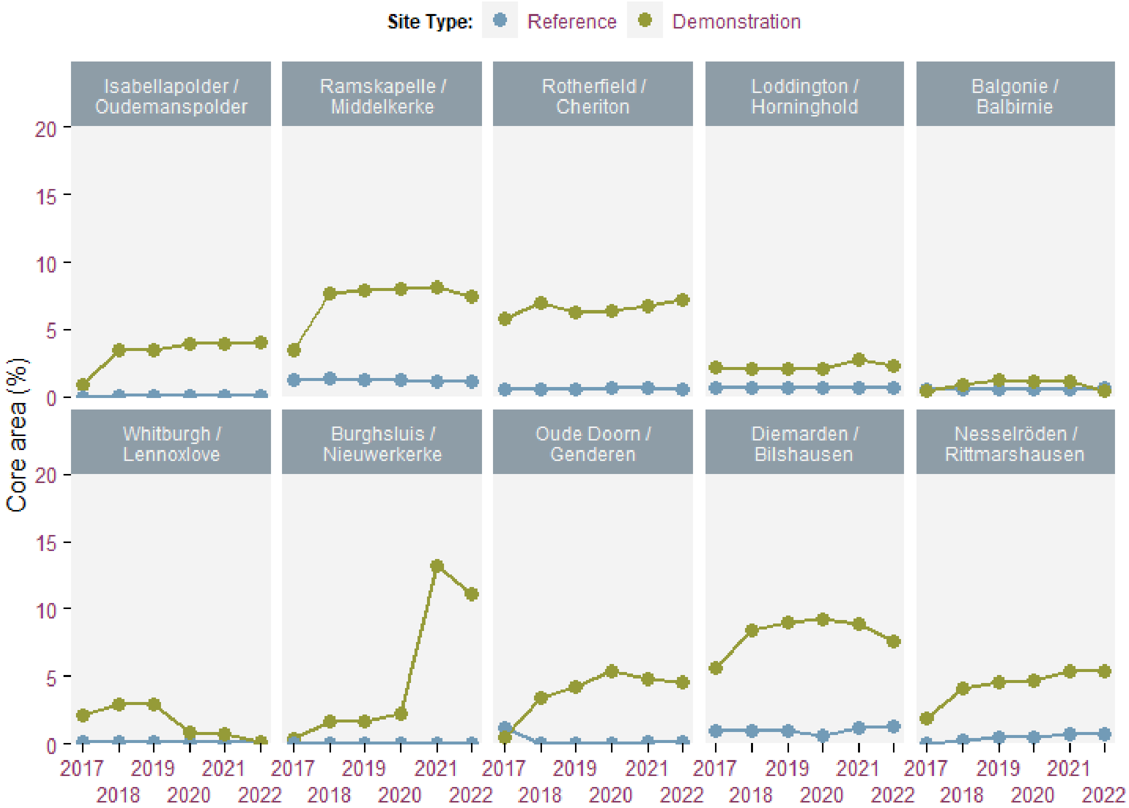


Figure 54: Changes over time in the proportion of the landscape occupied by core nesting habitat at our project sites.

We detected a significant interaction between site type and time on the percentage of the landscape occupied by core nesting habitat at our project sites ($F_{(1, 98)}$ = 8.30, p = 0.005, Figure 54). We found that the amount of core nesting habitat significantly increased, by an average of 2.7%, at our demonstration sites over the course of the project ($F_{(1, 49)}$ = 11.24, p = 0.002) – whilst we found no significant change at our reference sites ($F_{(1, 49)}$ = 0.80, p = 0.375).

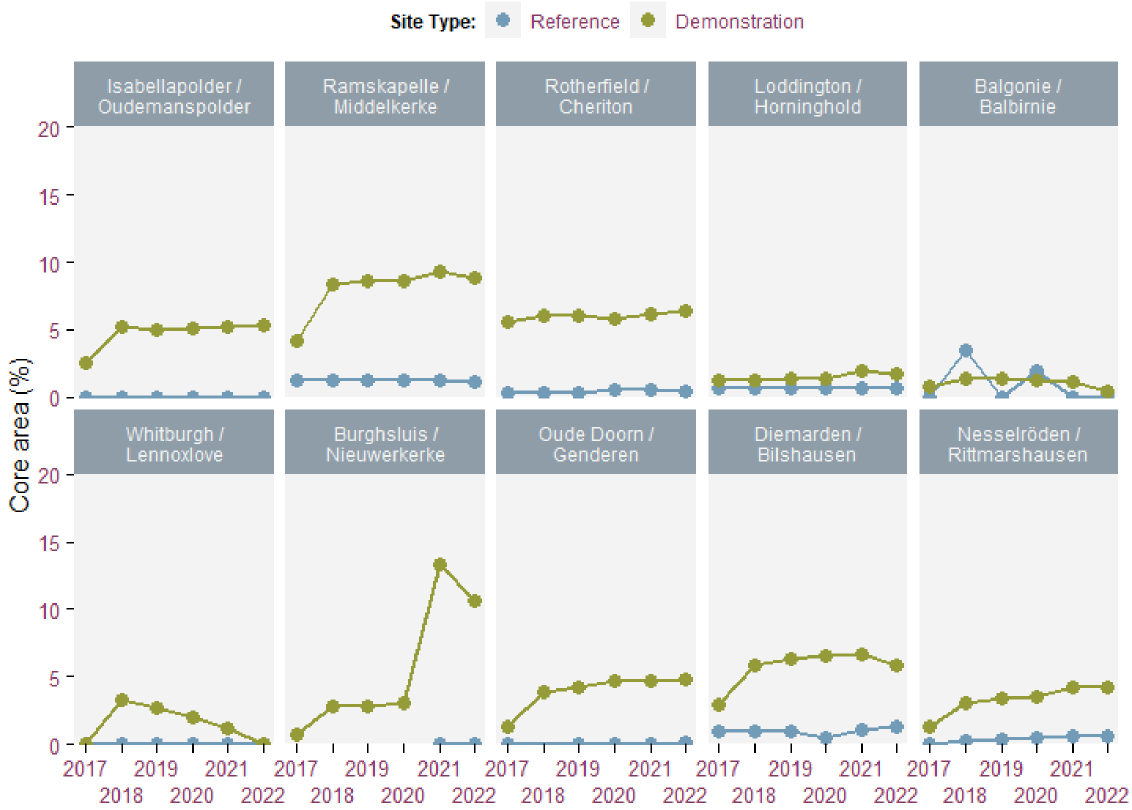


Figure 55: Changes over time in the proportion of the landscape occupied by core brood-rearing habitat at our project sites.

We also detected a significant interaction between site type and time on the percentage of the landscape occupied by core brood-rearing habitat at our project sites ($F_{(1, 98)} = 6.89$, p = 0.010, Figure 55). The proportion of core brood-rearing habitat within our demonstration sites was found to have significantly increased, by 2.7%, over the course of the project ($F_{(1, 49)} = 12.09$, p = 0.001) whilst the amount at our reference sites did not change significantly ($F_{(1, 49)} = 0.46$, p = 0.501).

Discussion

Establishing and improving beneficial habitat

The primary objective of collecting habitat monitoring data was to measure the PARTRIDGE project's progress towards achieving its goal of establishing at a minimum of 7% of wildlife-friendly habitat (i.e., those habitats we determined provided *nesting, brood-rearing* or *overwinter cover* benefits for grey partridge and other ground-nesting birds) at our demonstration sites. Although every effort was taken to select demonstration sites indicative of typical farmland in each of our partner regions, we found mid-way through the project that, at the onset of the project, our demonstration sites were covered by, on average, 8.8% beneficial summer habitat - already achieving our aim of 7% beneficial habitat. This may be partially explained by the proviso that the demonstration sites needed to have grey partridges (*Perdix perdix*) recently recorded as being present and needed to be managed by farmers willing to engage with our demonstration project. Consequently, we ended up with demonstration sites that were 1) either managed by farmers who were already predisposed towards wildlife-friendly farming, and thus were likely to have some kind of beneficial measures already, or 2) demonstration sites where we had worked before, and which already had some of our promoted wildlife-friendly measures in place.

The average of 8.8% coverage of wildlife-friendly habitat stated above is still below the more recently cited 10% threshold that is believed to be required to be set aside to significantly benefit, and therefore help recover, farmland biodiversity (Busch *et al.*, 2020; Sharps *et al.,* 2023). However, over the course of the PARTRIDGE project we successfully increased the uptake of AE scheme measures and the establishment of beneficial habitat within our demonstration sites, with an average 13.7% of demonstration sites covered by these habitats in 2021, or an average increase of 4.9% of the farmed landscape. Likewise, we increased the amount of summer habitat benefitting brown hare at our demonstration sites over the course of the project – increasing from an average of 9.3% in 2017 to 12.5% in 2022, resulting in a significant, almost twofold, increase in the abundance of hares at our demonstration site compared to our reference sites (Petersen, De Bruyn and Scheppers *et al.,* 2023). This was achieved primarily through the ability of our project site managers to provide specific, expert advice to all our farmers – communicating the importance of establishing these beneficial habitats, and ensuring farmers were confident in their ability to implement and manage these additional habitats correctly. Also important was the information exchange between the PARTRIDGE partners themselves, allowing us to overcome any issues encountered during the establishment of these novel habitats, but also to allow farmers to see our proposed management techniques in practice on other farms or sites before implementing these techniques for themselves. The ability for us to show-case our beneficial habitats and management techniques to farmers was integral to the successful increase in these habitats across our demonstration areas.

Previous studies have indicated that, to effectively recover grey partridge, arable land must be comprised of at least 5% brood-rearing habitat and 6.9 km/km^2 nesting cover in the absence of effective predation control (Aebischer and Ewald, 2004). We found that, at its peak in 2021, our demonstration sites had an average of 11.1% of their site covered by brood-rearing habitat. Aebischer and Ewald (2004) only considered linear hedgerows as nesting habitat, whilst we considered both linear and areal features as nesting habitats. We used half the length of the perimeter of our nesting habitats, which at its peak in 2021 equalled an average of 13.8 km/km^2 of nesting cover at our demonstration sites, to compare with Aebischer and Ewald (2004). The amount of both brood-rearing and nesting cover provided on our demonstration sites was more than double that set out by Aebischer and Ewald, 2004 to have significantly recovered grey partridge populations. Our monitoring results show that the breeding territories of grey partridge increased by 70% over the course of the project (Petersen, De Bruyn and Scheppers *et al.,* 2023), demonstrating the positive impact of our chosen beneficial habitat measures on grey partridge.

An example of beneficial habitat at the Balgonie demonstration site, in this case a pollinator mix aimed at benefitting both insects and grey partridge in fields of potatoes. © Fiona Torrance

Two demonstration sites fell below the target of 7% of their area covered by beneficial habitat in the final year of the project. This was the case at our two Scottish sites, Whitburgh and Balgonie. At the latter site, Balgonie, this was caused by two factors – namely the removal of several hectares of wild-bird mix to accommodate a railway development project within the boundaries of the demonstration site, together with several additional hectares of beneficial pollinator habitat that were moved just outside the boundaries of the demonstration site. At Whitburgh, the failure to achieve the 7% target was primarily a result of all the blocks of PARTRIDGE wild-bird mix established at the project's start being replaced by less-effective canary grass mixes by the farm team midway through the project.

Measures of habitat heterogeneity

The beneficial habitat (*i.e.,* beetle banks, grass margins, pollen & nectar mixes, wild-bird mixes, extended overwintered stubbles, arable margins, headlands & vogelacker, and some semi-natural habitat) at our demonstration sites was significantly more heterogenous than the beneficial habitats on our reference sites. Higher levels of habitat heterogeneity within arable landscapes have been found to be positively correlated with species richness of farmland bird communities (Herzon and O'Hara, 2007; Wretenberg, Pärt, and Berg, 2010), which we also found with our monitoring results – both abundance of breeding territories and the richness of farmland birds was found to be greater at our demonstration sites than at our unenhanced reference sites, especially for small-scale landscape species such as the yellowhammer (*Emberiza citronella*) and skylark (*Alauda arvensis*) (Petersen, De Bruyn and Scheppers *et al.,* 2023).


A strip cropping project at the Burghsluis demonstration site, increasing the heterogeneity of crop habitat © Suzanne van de Straat

Whilst our project succeeded in increasing the richness of beneficial summer and winter habitat at our demonstration sites, these increases were not significantly different from the changes in richness of the same habitat at our reference sites. Whilst our project hoped to make our farmers more biodiversity-minded, and thus more likely to establish a diverse range of habitats, we primarily focused on the establishment of our wild-bird mixes and not on the diversification of habitat at our project sites. Thus, a greater focus on establishing a wider variety of habitat types may have resulted in more species of farmland bird recovering significantly at our demonstration sites.

All other measures of habitat heterogeneity, except for Shannon's diversity of winter beneficial habitat, did not significantly differ between our demonstration and reference sites. This reflects the fact that the area of the individual types of beneficial habitat were not evenly spread across our landscapes. This was not something that was possible to control, as some of the habitats we implemented are impossible to establish at the same scale as others. For example some beneficial habitats, such as grass margins and PARTRIDGE wild-bird mixes, are widely distributed across the landscape of our demonstration sites and are often the group of beneficial habitats which occupy the greatest area overall, representing 38% and 33% respectively of the total area of beneficial habitat at our demonstration sites in 2022, whilst other habitats are much smaller and more localized, such as beetle banks, which represent just 1% of the total area of beneficial habitat in the same year (Figure 2).

The lack of more clear distinctions of the heterogeneity of beneficial habitat between demonstration and reference sites was likely exacerbated as the PARTRIDGE project prioritised establishing blocks of wild-flower mixes over other types of beneficial habitats, as they were deemed able to provide the highest overall benefit to grey partridges and thus other farmland species. These habitats were relatively large, with an average patch size of 0.5 hectares to reduce predation risk. Therefore, the push for wild-flower mix blocks may be why there are not more clear differences between the heterogeneity of our demonstration and references sites, with the distribution of area amongst our different habitats being less equitable at our demonstration sites despite a greater richness of habitats.

Measures of landscape configuration

The spatial arrangement of the additional beneficial habitat established throughout the duration of the project is likely to have impacted the ability of farmland wildlife to utilise the resources they provide (i.e., nesting, or brood-rearing cover). We calculated several metrics of patch clustering, namely aggregation, normalised landscape shape, and clumpiness indices, alongside the Euclidean nearest neighbour distance between patches of beneficial habitat. The values for all three of the indices indicated that beneficial habitats of all types, at both our demonstration and reference sites, were highly aggregated. In most cases, patches of beneficial habitat were not significantly more- or less-aggregated at our demonstration sites when compared to our reference sites.

Drone imagery showing the variety of shapes, sizes, and arrangements of beneficial habitats at the Isabellapolder demonstration site. In this instance, the beneficial habitats are aggregated with one another. © Korneel Verslyppe

The exception to this was the normalized landscape shape index of both nesting and brood-rearing habitat, which was slightly, but significantly, more aggregated at our demonstration sites than at our reference sites. The effects of habitat aggregation are mixed and species-dependent. In modelled scenarios increased habitat aggregation was found to be detrimental to farmland biodiversity through the loss of specialist species (Steiner and Köhler, 2003). In other literature it was found to have a positive effect on the diversity of invertebrate and avian species (Kennedy *et al.*, 2013; Wozna *et al.*, 2017), possibly by accommodating species with large habitat extent requirements in patchy landscapes

(Bennett, Radford and Haslem, 2006), or in the case of small populations by minimising the negative impacts of Allee effects (Kanarek *et al.*, 2013; Vortkamp *et al.*, 2020). Previous research suggests, but does not confirm, the presence of an Allee effect in our key species, the grey partridge (Watson, Aebischer, and Cresswell, 2007), with greater partridge density reducing predation risk *via* a shared burden of vigilance. Therefore, a more aggregated arrangement of our beneficial habitat for grey partridge may be of benefit.

Conversely, it may also be possible that, as the grey partridge is a territorial species especially during the pairing period, more aggregated habitat may be a detriment to our goal of recovering this species. The tight clusters of beneficial habitats may have meant that several patches fall within the radius of a single territory, thereby preventing these patches from being effectively utilised by other pairs and limiting the carrying capacity of the landscape. This is believed to be particularly the case in low-density grey partridge populations where pairs tend to have larger territories than in high-density populations (F. Buner, pers. com.). Thus, a more even distribution of habitat, spread throughout the landscape, could have enabled a greater carrying capacity of grey partridge within our demonstration sites. This arrangement of habitat has been suggested elsewhere, albeit benefitting grey partridge through a reduction in losses to predation (Panek and Kamieniarz, 2000).

Nesting and brood-rearing habitat was often less aggregated at our Scottish and English demonstration sites than at our German, Dutch, and Belgian sites (Figure 19; Figure 21; Figure 23). This differing level of aggregation may reflect the differing land ownership structures between Great Britain and continental Europe. At our English and Scottish sites our entire demonstration sites are farmed and managed by just one or two farmers, whereas our demonstration sites in the Netherlands, Belgium and Germany were comprised of several, smaller farms – with between 9 and 56 individual farmers at each of these sites. However we could not find a significant relationship between the number of farmers on our sites and the level of habitat aggregation.

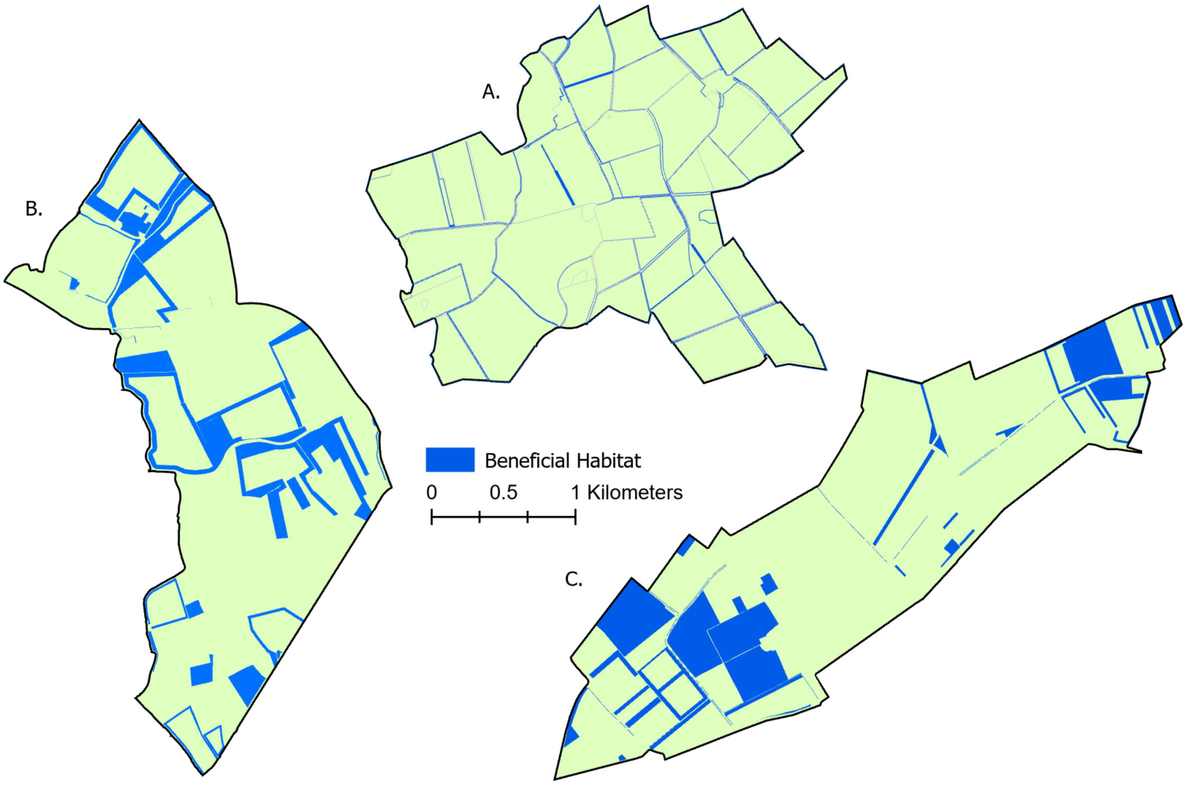


Figure 56: Maps of less aggregated beneficial habitat at Whitburgh, SC (A) compared to more aggregated habitat at Ramskapelle, BE (B) and Burghsluis, NL (C). The gaps between habitats in the latter two sites indicates where it has not been possible to establish beneficial habitat.

Where several farmers are involved in managing an area, it is far harder to ensure an even distribution of beneficial habitat across the landscape. Each individual farmer will have different preferences as to where on their land any new habitat is established - or may even elect not to engage in the project whatsoever and not establish any habitat. Similarly, some farmers on our demonstration sites were dairy and/or cattle farmers who were unable or unwilling to give up their pastureland for wildlife, while others offered up large fields of several hectares in a 'have it all or leave it altogether' manner. This was typically the case where a farmer owned or rented an isolated field, away from their main block of land. By examining the location of beneficial habitat on a map it is easy to see areas where, for a multitude of reasons, it has not been possible to establish beneficial habitat - leaving noticeable 'gaps' within our mosaic of beneficial habitat (Figure 56).

We found that the density of habitat edge (i.e., the boundary where beneficial habitat meets other habitat) at our demonstration sites was significantly higher at our demonstration sites for both brood-rearing and overwinter cover habitat, with the average amount of edge habitat per hectare at our demonstration sites up to 56% greater compared to our reference sites. The effect of habitat edge on bird species is mixed (Sanderson *et al.*, 2009; Zurita *et al.*, 2012). In some cases, it is detrimental and poses an increased risk of predation, especially where edge habitats are particularly narrow and create predator traps (Morris and Gilroy, 2008; Laux, Waltert, and Gottschalk, 2022), and in other cases it has a significant positive effect on bird diversity (Reino *et al.*, 2009; Whittingham *et al.*, 2009). We found that the distance between patches of brood-rearing habitat at our demonstration sites was significantly less than that at our reference sites, being spaced just 27 m apart at our demonstration sites in 2022. This concentration of habitat edge within a small space, combined with the associated increased predation risk of edge habitat, may have constituted an ecological trap for grey partridge and made them more susceptible to predation (Bro *et al.,* 2004), despite our promotion of larger blocks of wild-flower mixes to prevent this.

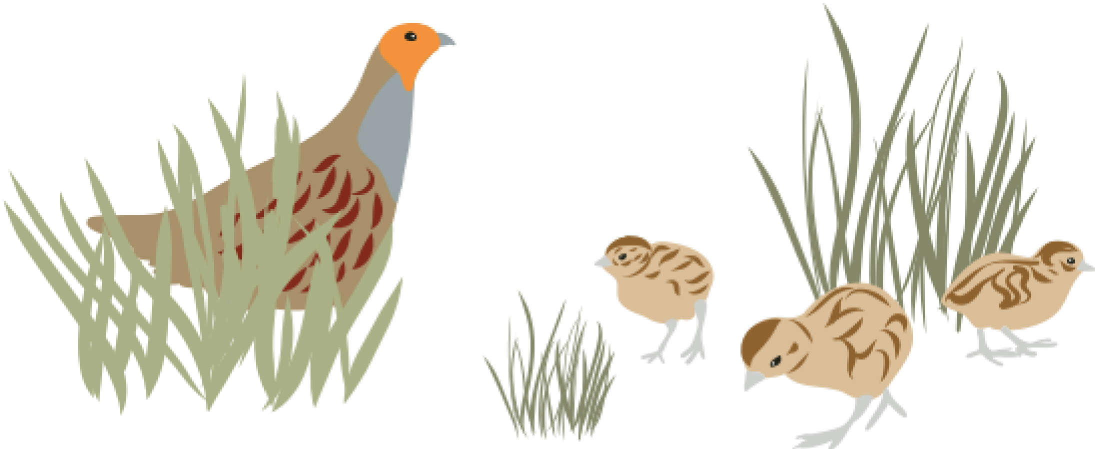
Measures of habitat shape and size

Whilst we did not consistently measure the quality of habitats established throughout the project at our demonstration sites (e.g., floristic diversity or density of flower mixes) we attempted to measure quality indirectly by investigating the shape and size of our beneficial habitats. Among the numerous metrics of habitat shape and size we considered, (fractal dimension index, perimeter-area ratio, shape index, and mean patch size), we found no significant differences between beneficial habitat patches at our demonstration and reference sites. This is despite our focus on establishing large blocks of wild-bird mix, which ought to have affected the habitat shape and size metrics. This can be explained as, despite the fact these wild-bird mixes occupied a considerable proportion of the beneficial habitat at our demonstration sites (up to 34% of all beneficial habitat; Figure 2), the majority of the other beneficial habitats were either established through AE schemes, and thus would have their dimensions mandated through the proscriptions of these schemes, or were pre-existing semi-natural habitat, the size of which would likely be consistent within the landscape.

An example of a 2nd (on the left of the photo) and 3rd (on the right of the photo) year PARTRIDGE wild-bird mix. We aimed to ensure this measure was at least 0.5 ha in size to reduce predation risk. © Francis Buner

Another indirect measure of habitat quality we investigated was the abundance of core habitats at our project sites, and the average proportion of our beneficial habitats which fulfilled the requirements to be defined as ‘core habitat’. For our study species we defined 'core area' as any part of a beneficial habitat patch more than 10 meters away from the nearest habitat edge (i.e., a habitat must be at least 20 meters in width to accommodate core habitat) - reflecting the necessary width requirement to halve the risk of nest predation in grey partridge (Gottschalk and Beeke, 2014).

Although we found no difference in the average area of individual nesting and overwinter cover patches that were core habitat between our demonstration and reference sites, the average proportion of brood-rearing habitat that was core habitat was significantly larger at our demonstration sites than at our reference sites - by as much as three times larger in the final three years of the PARTRIDGE project. In addition, we found that the average proportion of the landscape occupied by core nesting and brood-rearing habitat was, in both cases, ten times greater across the final three years of the project at our demonstration sites than at our reference sites. These values both increased significantly over the course of the project – with the proportion of both core nesting habitat and brood-rearing habitat more than doubling between 2017 and 2022. Combined with the high levels of beneficial nesting, brood-rearing, and overwinter cover habitat at our demonstration sites, it is unlikely that a lack of habitat provision was responsible for the lower-than-expected biodiversity recovery on our demonstration sites.



Project complications

Across our significant metrics, there was no consistent pattern in many of the calculated landscape metrics (i.e., **both** demonstration and reference sites were changing over time – sometimes increasing, sometimes decreasing). Often, we found that any significant differences between our demonstration and reference sites were present from at least the onset of the project. This is even though a **significant** amount of additional habitat was established by farmers and hunters at our demonstration sites throughout the project.

One hypothesis as to the lack of significant changes in the landscape metrics is that this was caused by an 'end-of-project' effect. This reflected a decline in beneficial habitat in the final year of our project (with summer habitat decreasing from 13.7% in 2021 to 12.8% in 2022, Figure 5; and levels of winter habitat decreasing from 53.3% in 2021 to 48.7% in 2022 Figure A2-1). This would have decreased the difference between our demonstration and reference sites - obfuscating any significant trends over time in the demonstration sites. The reasons for this small downturn in beneficial habitat area in the final year of the project are unclear, but it coincides with several major geopolitical events which could have impacted farmer's decision-making. Possible reasons for this change are the Russian invasion of Ukraine and the effects this had on commodity and fertilizer prices, the reformatting of the common agricultural policy (CAP) ahead of a new CAP coming in to force in 2023, and the numerous consequences of Brexit.

Another proposed factor for the lack of significant change over time in our metrics is the high initial levels of beneficial habitat at our project sites (Figure 5). Despite our aim of selecting comparable demonstration and reference sites, fundamental differences between these pairs existed from the onset of the project. This is corroborated by the fact that many of our chosen metrics displayed significant differences between demonstration/reference pairs in the absence of any significant change over time. Thus, starting from a high initial value, we would have had to alter significantly larger areas of the landscape post-2017 to render a significant change over time.

Lastly, another complication with our chosen project sites was that almost all our demonstration sites were comprised of mixed farms. Recent research shows that the addition of bird-friendly AE scheme options to purely arable or purely pastoral landscapes (at levels comparable to those in our project) can effectively recover many of farmland birds we studied; however the effects on mixed landscapes such as ours is less clear (Sharps *et al.,* 2023). We lacked information on the provision of AE scheme habitats on the area surrounding our demonstration sites, and therefore cannot relate our findings to the theory of Sharps *et al.(2023)* - that surrounding sites rich in AE scheme habitats may encourage recovering species to emigrate from their AE scheme-rich study sites into surrounding areas of mixed farmland. Although the provision of bird-friendly habitat within our mixed farm systems was sufficient to increase both the abundance and diversity of our monitored species (Petersen, De Bruyn and Scheppers *et al.,* 2023), we may have seen a stronger effect had we worked solely on in arable or pastoral landscape.

Recommendations

Whilst the differences between our demonstration and reference sites in the metrics we have examined suggest that the former should have become more biodiverse in wildlife over time, we found that the project's efforts to improve the landscapes of our demonstration sites did not result in significant increases in individual species abundance (see companion reports – Petersen, De Bruyn and Scheppers *et al., 2023*). It may be the case that, as our demonstration sites already started with high levels of beneficial habitat, a maximal increase of 4.9% of beneficial habitat per site (representing approximately 25 ha additional beneficial habitat) may have been insufficient to significantly increase site biodiversity. Alternatively, beginning with such large amounts of beneficial habitat at our demonstration sites may have meant that the wildlife populations we monitored were close to or already at carrying capacity. An alternative explanation could be that the surplus of young produced did not return to breed at our demonstration sites, but instead dispersed outside our 500-ha areas to fill territory 'gaps' elsewhere. Or, in reverse, there were not enough individuals of our indicator species available outside our demonstration areas to immigrate onto our sites, thereby increasing breeding densities in our newly-established habitats. Our success was further hindered by the weather, with the spring of 2020 being exceptionally wet, while the summers of 2021 and 2022 were unusually hot and dry, the combination of which may have had negative effects on the breeding density of our indicator species.

Whilst our demonstration site selection was influenced by the need to select sites with recent records of grey partridge presence, future projects which aim to highlight the effects of habitat-establishment and proper management on biodiversity should therefore endeavour to select demonstration sites with lower initial levels of beneficial habitat.

The addition and management of beneficial habitat is not the only method by which arable biodiversity can be restored. Previous research has shown that the addition of effective predator management to arable landscapes has increased the breeding success of grey partridge by 2.6 times (Tapper, Potts and Brockless, 1996), and significantly increases the densities of brown hares (Reynolds *et al.,* 2009). When applied in tandem with habitat management, legal effective predator management can increase the densities of grey partridge populations sixfold (Tapper, 1999). Many successful grey partridge recovery projects have utilised legal, lethal predator control (Aebischer and Ewald, 2010; Draycott, 2012; Ewald et al., 2020).

That is not to say that legal effective predator control is *mandatory* when attempting to restore arable biodiversity. At several of our sites we were unable to implement legal effective predator control and still, in the case of the Diemarden demonstration site, recorded a significant increase in partridge densities (Petersen, De Bruyn, and Scheppers *et al*., 2023) – likely due to the high levels of beneficial habitat present at the site (13.0% at the end of the project). Therefore, we would recommend that future projects utilise legal effective predator control where possible, but in its absence aim to establish additional habitat to compensate – above 10% of the site area.

Lastly, our demonstration sites, despite being 500 ha in size, and hence far larger than a typical AE scheme farm agreement, may have simply been too small for us to have any significant impact on the biodiversity of the wider landscape. Many studies considering the effects of environmental heterogeneity on species diversity are at least twice the size of our individual demonstration sites (Stein, Gerstner, and Kreft, 2014, Aebischer and Ewald, 2010, Draycott, 2012, Ewald et al., 2020). Additionally, although environmental heterogeneity is an important driver of biodiversity, it is less so at small extents (Malanson *et al.*, 2023) than at intermediate extents (10,000 ha to 1,000,000 ha; Sarr, Hibbs and Huston, 2005). Therefore, we suggest that future efforts should take place at much larger spatial extents to properly capture the effects of any habitat management on biodiversity within the landscape. Sadly, we were not able to implement our project on larger areas despite considering 1,000 ha project sites at the beginning of the project development, simply because, as a demonstration project rather than a scientific experiment, such large areas were not feasible for our project partners to manage nor finance.

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Appendix 1 - Mapping articles:

Mapping protocol

Executive Summary

1. This mapping protocol is designed to ensure that the GIS maps created by the different partners are compatible and will allow analysis to be undertaken across all project demonstration and reference areas.
2. Standard habitat codes are detailed in Table A1-1, with codes for habitat management detailed in Table A1-2. Habitat codes will be reviewed yearly.
3. All elements within the landscape layer are to be digitized as polygons. Other GIS layers may need to use lines (fences) or points (feeders) but these must be in a separate GIS layer.
4. Standard mapping units are detailed in Section 4. Briefly, all mapped elements should have a minimum surface area of 100 m^2, linear elements should have a minimum width of 1.5 m, a maximum width of < 25 m and must be at least 50 m in length. Elements mapped as areas should be at least 25 m wide and at least 50 m in length.
5. The LAEA coordinate system (see details in Section 5 for details) is to be used for the Geo-referencing of the maps to be provided by partners for analysis. Partners may, of course, utilize their national coordinate system but MUST provide maps in the LAEA system. Metadata covering information on the images/maps used to create the GIS maps are also required on submission of the GIS maps.
6. Detailed instructions for mapping are given in Section 10.
7. Three maps per year need to be provided by each partner, so we can compare the results of hare monitoring (December/January), monitoring of grey partridge and other farmland bird breeding distribution (May/June) and grey partridge autumn monitoring (September/October) to habitat provision.
8. The habitat attribute table **MUST** include columns detailed in Table A1-3, in order that maps from different partners can be combined.
9. Maps of the outlines of the demonstration and reference areas will be needed from each partner. Details of the GIS file structure for this are presented in Table A1-5.
10. In addition to habitat mapping, this document outlines the information that needs to be mapped to represent the results of the biodiversity monitoring. This includes mapped layers for hare monitoring (transect and viewpoint counts), grey partridge monitoring (both spring – call counts and field counts- as well as autumn counts), as well as feeder, snare and trap locations and any fences used to protect nests. Details for the GIS files for these can be found in Tables A1-6 to A1-7 and A1-9 to A1-14.
11. Farmland bird monitoring data will be mapped through the AviMap system. Table A1-8 contains an outline of the GIS table that will be created in that system.

PARTRIDGE Habitat & Monitoring Mapping Protocol

1. AIMS and OBJECTIVES

In Work Package 3 our aim is to set up two 500 ha demonstration sites in each country, providing a minimum of 7% of high-quality wildlife habitats. In Work Package 4 we will measure the effects of this habitat provision, using three biodiversity (Grey Partridge, farmland songbirds and brown hare) and five ecosystem service indicators (pollination, soil quality and game bags). We will compare this provision and its effects to that on provided on an equal number of matching reference sites within the same region.

Mapping of both the demonstration and reference areas will be undertaken to monitor the provision of habitats within Work Package 3 and determine the relationship of this habitat provision to the biodiversity and ecosystem service indicators. These maps will need to:

Indicate what habitat was available at the beginning of the project.

Indicate where, when and how much habitat has been provided throughout the project.

Allow for the overlap of the collection of information on biodiversity and ecosystem service indicators on these habitat maps.

We will need to calculate the area, length, spatial distribution, and percentage of habitats available and added to each demonstration site and its matching reference site, throughout the time of the project.

2. PROPOSAL

There needs to be a minimum standard of mapping by all partners, as each are responsible for producing maps to cover their demonstration and reference areas. Maps will need to be reviewed on an annual basis across the PARTRIDGE Project to ensure that sufficient information is being recorded to meet the project's objectives. If maps are found to contain insufficient information to meet the project's objectives, it will be the responsibility of the national partner managing the areas in question to remedy this situation.

The minimum standard is to produce a map without gaps covering the habitats on both the demonstration and the reference areas, representing seasonal changes in habitat. All habitat elements will be mapped as polygons, including hedges, beetle banks, streams etc. Additional information such as points indicating solitary trees, lines indicating post and wire fences, etc. can be added as extra layers if desired. Year-on-year and season-by-season habitat maps will be needed to show the change in habitat provision and to represent the sites at different times of the year for comparison with data collected on biodiversity indicators. Seasonal mapping will take place in January and June of each year of the study.

The map of the landscape of each site (Demonstration and its Reference area) will include the following habitats as standard (for more details see Table A1-1):

- Semi-natural habitat (SNH)
- Established wildlife habitat (EWH)
- Crops
- Urban areas
- Water features
- Non-Habitat – man-made components of the environment, other than urban areas.

Other layers that will be required are:

1. Outlines of the boundaries of the demonstration and reference area, digitized as polygons.
2. Transects (used for monitoring hare, grey partridges call counts and farmland birds) will need to be digitized as separate layers as polylines. Layers holding buffers around transects will also be needed.
3. Viewsheds for monitoring hare will need to be digitized as polygons.
4. Mapped results from hare surveys (both methods of monitoring), grey partridge surveys (all methods of counting) and farmland birds will be needed for analysis. Hare and grey partridge results can be digitized onto layers within the GIS, with separate layers for each method, season, and year combination. Farmland bird data will be recorded and analysed initially in AVIMAP with data and results of analysis exported to GIS. Grey partridge locations will be digitized as points, as will the farmland bird raw data.
5. Mapped locations of any feeders, snares, traps, digitized as points.
6. Mapped locations of any exclusion fences, digitized as polylines.

3. HABITAT DEFINITIONS FOR LANDSCAPE MAPS

The crops at each site will be recorded as follows:

1. All crops/crop categories in the landscape sector will be recorded. The codes to be used for the crops are detailed in Table A1-1. If other crops common to the region are not included in the table, further crops and codes may be added.
2. Fields recently ploughed or fallow are to be recorded as cultivated bare ground (<30 vegetation cover), see Table A1-1.
3. Changes in crop management will be reflected in the seasonal mapping – i.e. going from plough to crop to stubble.
4. Rotational grasslands are to be classified as a crop. *The rotational grasslands < 5 years old and > 5 years old* will be recorded as different crops (Table A1-1). Interrupted grasslands (grasslands ploughed every 3 – 4 years and then sown with the same grass species) have also been allocated a separate crop category in Table A1-1, as has *rotational grasslands < 5 years old* that is established via undersowing or direct drilling – if this is known.

Depending on the site it may be necessary to map certain crops in more detail than the suggested categories throughout the landscape sector. It is up to the individual partners to decide what their special requirements are for their individual sites. These further categories should be shared across the partnership yearly to standardise any coding. Any crops added by the partner should follow the code format of Table A1-1 for the crop categories, i.e., a new crop would be placed within 2.'x', 3. 'x' and 4.'x'. A review of these codes will be done after the first year of mapping to ensure that partners are using as similar codes as possible.

The **urban areas** in the areas will be recorded throughout. It is suggested that the urban areas are not mapped in the field but taken from digital topographical maps if available. It is also possible to digitise the urban areas from aerial photographs. The urban areas are to be classified into 4 categories according to the amount of 'green area' within each element (see Table A1-1). This assessment (a rough estimation) can be undertaken prior or after field mapping using aerial photographs. For some sites a further categorisation of the urban areas may be necessary. Further categories added by the partners will be treated as site-specific. Any urban categories added by a partner should follow the code format of Table A1-1 for urban elements, i.e., 5.'x'.

Water bodies (both water course and ponds, lakes etc.) are to be recorded. Water courses > 1.5m wide (e.g., rivers, streams, canals, drainage ditches) can be selected from the topographical maps. These elements may be represented as line elements in the topographical maps. It will be necessary in such cases to buffer these elements to provide a width using the average width recorded for the element during on-site mapping.

All other habitats that DO NOT fall into the groups defined above will be classified as non-habitat. These habitats include roads, paved tracks etc. which will be mapped separately as a category of non-habitat. Unpaved roads will be digitised as a separate category. We realise that some of them may, in fact, serve as partridge habitat but we will include them in this category at this time.

4. SPATIAL RESOLUTION AND EXTENT

The minimum mapping unit (MMU) definitions are as follows:

1. Any element (SNH, EWH, crop, urban area, water body) selected for mapping in the landscape sector needs to have a minimum surface area of 100 m^2, to guarantee a minimum impact on the indicators. If there are obvious features that cannot be combined with other features surrounding them that covers less than 100 m^2, these can be added as polygons but do not sub-divide habitats unnecessarily.
2. SNH & EWH Linear Elements (WL, HL) should have a minimum width of 1.5 m and a maximum width of < 25 m. They must be at least 50 m in length.
3. SNH & EWH Areal Elements (WA, HA, FA) should be at least 25 m wide and at least 50m in length.
4. The remaining elements (crops, water bodies, urban areas) must be a minimum width of 1.5 m and at least 50 m in length.

5. GIS & GEO-REFERENCING SYSTEM

The LAEA coordinate system (see details below) is to be used for the Geo-referencing of the maps. For digitising purposes partners, may if they wish, use the system typical for the country/region of the case study. This may be especially relevant if other available digital data (aerial photographs, topographical maps) are projected in this system. It is recommended to use the LAEA geo-referencing system from the beginning rather than converting the data at a later stage. It is the responsibility of the partners to convert their maps to the LAEA system before data transfer if they chose to use another system beforehand.

The details of the geo-referencing system are as follows:

Coordinate System:
Lambert_Azimuthal_Equal_Area
False_Easting: 4321000,000000
False_Northing: 3210000,000000
Central_Meridian: 10,000000
Latitude_Of_Origin: 52,000000
GCS_ETRS_1989
Datum: D_ETRS_1989
Prime Meridian: 0

```
PROJCS
 ["ETRS_1989_LAEA",
  GEOGCS ["GCS_ETRS_1989",
        DATUM ["D_ETRS_1989",
             SPHEROID ["GRS_1980",6378137.0,298.257222101]],
        PRIMEM["Greenwich",0.0],
        UNIT["Degree",0.0174532925199433]],
  PROJECTION["Lambert_Azimuthal_Equal_Area"],
  PARAMETER["False_Easting",4321000.0],
  PARAMETER["False_Northing",3210000.0],
  PARAMETER["Central_Meridian",10.0],
  PARAMETER["Latitude_Of_Origin",52.0],
  UNIT["Meter",1.0]]
```

The GIS system used for digitisation will depend on the availability of the program to the case study partner.

6. ELEMENTS IN MAPS

All elements within the landscape layer are to be digitised as polygons in the map provided for landscape recording.

It may be necessary for some partners to digitise point elements for landscape recording. For example, some partners may be particularly interested in the distribution of solitary trees within their landscape sector and may need to map and digitise these elements. Point elements are beyond the minimum standard of mapping that is required but may be added to the maps if required – as a standalone layer. Some elements, such as hedges, will be digitised as polylines, with buffering used to construct the requisite polygon.

7. METADATA

Please attach the minimum metadata to each map:

1. Projection system
2. GIS system used for digitisation
3. Source of aerial photographs or satellite images
4. Source of base maps (detailed enough to recreate the mapping procedure)
5. Additional codes beyond those in Table A1-1 that you have used, together with a definition of what they stand for. For example, the additional SNH, crop, urban and water body codes that you added, management codes that you added etc.

8. DATA TRANSFER

For data transfer purposes the GIS data of EACH individual area should be exported as a shape file – demonstration and reference area need to be exported as separate files.

9. OVERVIEW OF MAPPING PROCEDURE

The suggested mapping procedure for each area is as follows:

1. Define the outline of the sites (Figure A1-1, Rotherfield site).
2. Use digital base maps (topographic, aerial photographic) to identify and outline SNH, urban areas, water courses and permanent crops in your landscape sector (Figure A1-2). This step can save mapping time in the field but is entirely up to the partner as to whether they undertake this procedure.
3. Assess urban areas for the percentage of 'green area' within the individual urban elements (see Table A1-1 for codes). This step may be undertaken before mapping or during the attribution phase of the maps described in step 6 below.
4. Undertake any digitization possible using the base maps and the aerial photographs.
5. Prepare the aerial photographs and/or planimetric maps ready for the field mapping (Figure A1-3).
6. Undertake the field mapping.
7. Digitise and attribute your maps in GIS, attach metadata.
8. Validate your data, e.g. topology of maps, codes in attribute table.

Figure A1-1. Rotherfield demonstration site.

10. DETAILED MAPPING PROCEDURE FOR HABITAT MAPPING

<u>Step 1, defining your study area.</u>

1. Identify the location of your demonstration and reference areas.
2. Digitise a boundary of the these, this will form one layer of the mapping necessary for the project. This outline will be the area used
3. Buffer 100 m around the boundary, this outline will cover the area you need to record habitat in.

Step 2, use digital base maps (topographic and/or cadastral) to select certain SNH (trees, hedges etc.), water courses, urban areas, and crop elements. (It is **strongly recommended** to utilise base maps if available. It is up to the individual partners as to whether they decide to undertake this step as all elements can also be mapped in the field.)

1. Preparatory work on the delineation of major elements within the landscape sector from aerial photographs, maps and/or satellite images is strongly recommended. The following source are recommended from the European project EBONE (Bunce et al., 2011):

a. The most recent 1:10,000 scale base map including topographic and/or cadastral information is suitable, enlarged to 1:5,000 scale for working with in the field.

b. Aerial photography (AP) prints at the scale of 1: 5,000. Aerial photographs should preferably be ortho-photos or else geometrical properties need to be assessed.

c. Digital outlines of the AP interpretation held on a field computer as well as any information in the field recorded directly.

d. Maps derived from satellite imagery. Image segmentation offers a further option for preparation before going into the field, if available.

2. If a base map (topographic and/or cadastral) is available you can select the digitally available SNH, water courses, urban areas, and crop elements within your landscape sector. Some of these elements will be available as polygons and others as line elements, which can be incorporated into a draft map before you go to the field.

3. Linear elements that are available from base maps (e.g., potentially hedgerows, small water courses) will need buffering to produce polygon elements during digitisation. The width of the buffers can be added after noting the width of these elements during field mapping. Roads could also be selected from the digital maps and buffered according to the widths already defined in the base maps if they are available only as lines. In this case, the delineation of roads in the landscape sector can be undertaken as part of the field preparation. Roads are to be classified as non-habitat in the attribute table, except for unpaved roads (see Table A1-1).

4. Urban areas, if possible, are to be selected from the base maps. During attribution of the maps the amount of 'green area' will need to be estimated

5. The digital SNH elements that are likely to be available for your sector are WA elements, e.g., forest, shrub. Linear elements such as hedgerows may also be available digitally and can be added to the base layer.

6. The digital crop elements that may be available are likely to be vineyards, olive groves and high-stem orchards. Outlines of fields should be available on the base map.

Step 3: Assess urban areas for percentage of 'green area' within the elements. The urban areas are to be classified into 4 categories according to the amount of 'green area' within the element (see Table A1-1). This assessment (a rough estimation) can be undertaken prior or after field mapping using aerial photographs.

Step 4: Undertake any digitization possible using the base maps and the aerial photographs. As much as possible, using the base maps and aerial photographs available to you, digitise an initial map within the GIS (using the requisite data format and projection, etc.).

Step 5. Gather both digital and paper copies of the available mapped information for use in the field. Produce paper maps (base and aerial photos) to take into the field at the 1:5000 scale. Transfer any digital maps to the field computer and confirm that you can access them on this computer.

1. Underlay the aerial photographs for the sector with the data prepared in steps one and two of Figure A1-1.
2. This step is undertaken in preparation of the field mapping.
3. The aim is to produce a 'working map' that can be used to map the remaining elements in the field.
4. The form of the 'working map' is up to the individual partners. It is recommended by Bunce et al. (2011) that the aerial photograph and prepared data should be enlarged to a scale of 1: 5,000. In any case, the scale used should enable the partner to easily draw the elements on the 'working map'. If preferred/available a field computer may also be used.
5. Hard copy map to take into the field for recording information.

Step 6: Mapping the landscape sectors

Mapping habitat needs to be done two times a year, to reflect the biodiversity measurements taking place in the project. These are hare monitoring (December/January) and grey partridge and other farmland bird breeding distribution (May/June).

A recording sheet for the mapping and necessary field information (habitat & management codes, SNH definitions) is to be found in the Appendix at the end of this document. Number each element mapped, starting with '1', on the recording sheet and mark the corresponding element on the map. For each element record the information relevant as detailed in the recording sheet, e.g., habitat type, height, width.

In the field the following will be mapped:

1. ALL the habitat types present in the landscape sector will be mapped (Table A1-1)
2. All crops as outlined in Table A1-1 will be mapped throughout the entire demonstration and reference areas.
3. For ALL Linear SNH and EWH an estimated width in metres of the element will be noted on the recording sheet or directly on the aerial photograph.
4. For ALL Linear SNH an estimated height in metres of the element will be noted on the recording sheet or directly on the aerial photograph. The height measured is to be an 'average' estimation for the element at the edge of the linear habitat being mapped.
5. For ALL natural or semi-natural woody areas an estimated height in metres of the element will be noted on the recording sheet or directly on the aerial photograph. The height measured is to be an 'average' estimation for the element at the edge of the aerial habitat being mapped.
6. For ALL water courses, a width in metres is to be recorded, for buffering purposes.
7. For ALL orchards a management code will be allocated (see Table A1-2 for codes).
8. For ALL grasslands a management code will be allocated. A management code will firstly be allocated to indicate whether the grassland is permanent or rotational (if rotational then whether established through direct drilling or undersowing) and a further code to indicate mowing, grazing, hay cutting or multiple systems (see Table

A1-2 for codes). In the notes there should be some mention of the type of livestock grazing – if any.

9. Other elements that are relevant will be mapped, i.e., location of feeders, location of bunches of scrub, brambles, thorns (woody point element, with buffer reflecting size).
10. The remaining elements need not be mapped but can be defined in the GIS environment as non-habitat, e.g., roads etc.

Step 7: Digitise the maps in GIS, validate and transfer data.

1. Digitise the elements that you mapped for your landscape sector in GIS
2. The geo-referencing system should the LAEA coordinate system (see section 5)
3. The unit of the GIS is metres
4. All elements are to be digitised as polygons
5. If you recorded solitary trees in your region these should be digitised as points on a separate layer, feeders (also digitised as points) should be on another separate layer.
6. The data to be recorded in your attribute table is detailed in the next section
7. Metadata should be attributed to the maps (see section 7).
8. The data should be validated, e.g., topology of the maps, codes in the attribute table. Once the validation of data entry is completed then on-site validation by those undertaking biodiversity monitoring should be undertaken.
9. Shape files should be used to transfer GIS data to other partners. Individual shape files (that include the LAEA geo-referencing system) for each sector should be used.

11. THE ATTRIBUTE TABLE

The habitat attribute table **MUST** include columns detailed in Table A1-3. Each partner should use the same format for the column names and the codes in Table A1-3.

12. PRACTICALITIES AND ESTIMATED EFFORT

Preparation for the field mapping (steps 1 to 4) will probably take around 4 weeks per site (both demonstration and reference) – i.e., one month.

For the field mapping (step 5) it is most efficient if you use a team of two people (driver + mapper). It is estimated that you will need 20 days for the mapping per site initially. After the initial mapping, seasonal updates will take 2 days per site.

The digitising and completion of the attribute table will also take around 4 weeks per site (steps 6 & 7) – i.e., one month.

13. OUTLINE OF REFERENCE AND DEMONSTRATION AREAS

A layer holding the outline of the reference and demonstration areas will be needed to assist with analysis, etc. This will be digitised as polygons (with holes indicating areas not included). The geo-referencing system, metadata and data transfer procedures will be as per the habitat mapping protocol.

PARTRIDGE Biodiversity Indicator Mapping Protocol

In addition to habitat mapping, information needed to interpret the results of the monitoring of the biodiversity indicators will be recorded within a GIS. The geo-referencing system, metadata and data transfer procedures will be as per the habitat mapping protocol.

1. DATA ON THE HARE MONITORING WILL BE RECORDED IN TWO WAYS.

1. Hare Transects.
2. Viewsheds – point data recording the number of hare in each viewshed, from a viewpoint.

2. DATA ON GREY PARTRIDGE MONITORING WILL BE RECORDED AS:

1. Walked playback pair counts.
2. Driven pair counts.
3. Driven covey counts.

3. DATA ON FARMLAND BIRD MONITORING WILL BE RECORDED AS:

1. Breeding bird survey transects.

4. DATA ON SOME MANAGEMENT OPTIONS WILL BE RECORDED AS:

1. Feeder locations.
2. Snare locations.
3. Trap locations.
4. Exclusion fences.

5. HOW TO MAP TRANSECT DATA

Transects will be mapped as polylines to record the monitoring of the biodiversity indicators, each on a separate layer. Separate transects (and map layers) will be required for each year of monitoring; if the transects change from year-to-year then the data needs to reflect this. At a minimum, individual layers of polylines will be required for the following monitoring exercises utilising transects:

1. Transects used for hare counting. (Table A1-6 for GIS attribute data set-up.)

2. Monitoring Grey Partridge density through playback (Table A1-9 for GIS attribute data set-up).
3. Farmland bird transects. Data on the location of Farmland birds will be recorded using the Avimap app (https://www.sovon.nl/nl/content/avimap). Analysis will be undertaken using the app and associated software.

6. MAPPING AREAS FOR BIODIVERSITY RECORDING

In addition, separate map layers will be required for the following, on a yearly basis (again if the area monitored changes the yearly maps need to reflect this), which will be mapped as polygons:

1. Viewsheds reflecting the areas that can be seen using point counts to monitor hare density. (Table A1-7 for GIS attribute data set-up).
2. Areas covered using four-wheel drives to record Grey Partridges in spring and in autumn (separate layer for each season). (Tables A1-10 and A1-11, respectively, for GIS attribute data set-up.)

7. MAPPING POINTS FOR BIODIVERSITY RECORDING

Separate map layers of points (if the area monitored changes the yearly maps need to reflect this) will be used to map the following:

1. Viewpoints used for monitoring hare density. Yearly layers will be required to show the areas surveyed each year as there may be times when a field/viewshed is not surveyed. (Table A1-7 for GIS attribute data set-up).

8. MAPPING MANAGEMENT

Aspects of management, in addition to habitat provision will be recorded within a GIS (again if the area monitored changes the yearly maps need to reflect this). These will be recorded onto individual layers and will include:

1. Locations of feeders providing overwinter food resources – recorded as points. (Table A1-12 for GIS attribute data set-up.)
2. Locations of snares/etc. used for controlling predators – recorded as points. (Table A1-13 for GIS attribute data set-up.)
3. Outlines of fences used for predator exclusions. – recorded as polylines. (Table A1-14 for GIS attribute data set-up.)

REFERENCES

Bunce et al. (2011) Handbook for surveillance and monitoring of habitats, vegetation and selected species, Alterra report 2154.
Information on research and recording of ecosystem services by the European Union can be found here: http://biodiversity.europa.eu/maes/#REPORTS

Tables

Habitat Codes

[1]It may be necessary to include more detail or further crops in the definition of crops. These will need to reviewed on a yearly basis.

Table A1-1. Habitat codes for the map attribute table.

HABITAT	Code
Semi-natural habitat (SNH)	
WA: natural or semi-natural wood	1.1
WA: woodland ride	1.1.1
WL: woody linear elements (UNSPECIFIED)	1.2
WL: new hedge (< 5 years old)	1.2.1
WL: dense wide hedge (>3m) with no or very few trees (max 1 per 100m) and suitable grass margin for nesting, height max 5m	1.2.2
WL: narrow hedge (<3m) with no or little ground cover (winter cover) but suitable nesting cover	1.2.3
WL: hedge with little or no ground cover (winter cover) and not suitable nesting cover (no old grass margin or cut during breeding season)	1.2.4
WL: hedge with 2-10 trees per 100m	1.2.5
WL: tree hedge (predominantly a line of trees or uncut hedge, higher than 5m)	1.2.6
WL: woody point elements (bunches of brambles, shrubs)	1.2.7
WL: woody area elements (extensive grassland with some shrubs)	1.2.8
HA: herbaceous areal elements (permanent fallow)	1.3
HA: herbaceous areal elements (weedy ephemeral fallow)	1.3.1
HA: herbaceous areal elements (legume ephemeral fallow)	1.3.2
HL: herbaceous linear elements (UNSPECIFIED)	1.4
HL: herbaceous linear elements (field boundary)	1.4.1
HL: herbaceous linear elements (buffer strip)	1.4.2
HL: herbaceous linear elements (ditchside)	1.4.3
HL: herbaceous linear elements (verge)	1.4.4
Parkland	1.4.5
Established wildlife habitat in Scheme (EWH)	
Beetle banks – linear element	1.6
Conservation headlands – linear element	1.7.1
Unharvested crop (Vogelacker) – areal element	1.7.2
Cultivated uncropped margin or arable margin - linear	1.7.3
Unharvested crop – linear element	1.7.4
Floristically enhanced grass margin (cut after 1 August)	1.8
Floristically enhanced grass margin (cut before 1 August)	1.8.1
Floristically enhanced grass margin (partially cut after 1 August)	1.8.1.1
Floristically enhanced grass margin (partially cut before 1 August)	1.8.1.2
Grass margin (partially cut after 1 August) – linear element	1.8.2

Grass margin (partially cut before 1 August) – linear element	1.8.3
HABITAT	Code
Grass margin (entirely cut after 1 August) – linear element	1.8.4
Grass margin (entirely cut before 1 August) – linear element	1.8.5
Grass margin (partially cut after 1st August) – Areal element (>15m wide)	1.8.6
Grass feature (cut after 1st August) – Areal element (>15m wide, floristically diverse)	1.8.6.1
Grass feature (cut before 1st August) – Areal element (>15m wide, floristically diverse)	1.8.6.2
Grass feature (cut after 1st August) – Areal element (>15m wide)	1.8.6.3
Grass feature (cut before 1st August) – Areal element (>15m wide)	1.8.6.4
Floristically enhanced meadow	1.8.7
Floristically enhanced meadow- cut	1.8.8
Floristically enhanced grass meadow (>8m, cut after 1st August)	1.8.9
Floristically enhanced grass meadow (>8m, cut before 1st August)	1.8.10
Wild-bird cover in first year – linear element (< 15m wide)	1.9.1
Wild-bird cover in second year – linear element (< 15m wide)	1.9.2
Wild-bird cover older than 2nd year – linear element (< 15m)	1.9.3
Wild-bird cover in first year – areal elements (> 15m wide)	1.9.4
Wild-bird cover in second year – (>15m wide)	1.9.5
Wild-bird cover older than 2nd year – (> 15m)	1.9.6
Wild-bird cover (Sprayed off)	1.9.7
Pollen & Nectar Mix in first year – linear element	1.10.1
Pollen & Nectar Mix older than 1st year – linear element	1.10.2
Pollen & Nectar Mix in first year – areal element	1.10.3
Pollen & Nectar Mix older than first year – areal element	1.10.4
Winter stubbles - sterile	1.11.1
Winter stubbles – naturally weedy	1.11.2
Winter stubbles – enhanced with seed mix	1.11.3
Winter stubbles – maize	1.11.4
Winter stubbles – undercut	1.11.5
Winter stubbles – Lucerne	1.11.6
Extended overwintered stubbles – naturally weedy	1.12.1
Extended overwintered stubbles – enhanced with seed mix	1.12.2
Lapwing plots	1.13
Field corners	1.14
Lucerne/Clover Red Kite plots	1.15
Canary Grass	1.16
Legume and herb-rich grass feature	1.17
Low input cereal (Crop specifics in REMARKS)	1.18

Crops	
Annual herbaceous Crops	
Cultivated Bare Ground	2.1
Winter Fallow Plough	2.1.1
Winter cereal stubble (sterile)	2.1.2
Winter cereal stubble (weedy)	2.1.3
Winter maize stubble (sterile)	2.1.4
Winter maize stubble (weedy)	2.1.5
Winter sown Wheat (*Triticum aestivum* & associated *spp.*)	2.2.1
Winter sown Spelt (*Triticum spelta* & associated *spp.*)	2.2.1.1
Spring sown Wheat (*Triticum aestivum* & associated *spp.*)	2.2.2
Winter sown Barley (*Hordeum sativum*)	2.3.1
Spring sown Barley (*Hordeum sativum*)	2.3.2
Winter sown Oats (*Avena sativa*)	2.4.1
Spring sown Oats (*Avena sativa*)	2.4.2
Spring sown Oats (*Avena sativa*) undersown with Peas (*Pisum spp.*)	2.4.2.1
Rye (*Secale cereale*)	2.5
Triticale (hybrid between wheat & rye)	2.6
Rice (*Orysa sativa*)	2.7
Sugar beet (*Beta oleracea*)	2.8
Fodder crops (e.g. *Brassica oleracea*)	2.9
Fodder beet (*Beta vulgaris*)	2.9.1
Potato (*Solanum tuberosum*)	2.10
Field beans (*Vicia faba*)	2.11
Peas (all types) (*Pisum spp.*)	2.12
Maize (*Zea mays*)	2.13
Winter sown Oilseed rape (*Brassica spp.* hybrid)	2.14.1
Spring sown Oilseed rape (*Brassica spp.* hybrid)	2.14.2
Sunflower (*Helianthus annuus*)	2.15
Pumpkin (all types) (e.g. *Cucurbita spp.*)	2.16
Spinach (*Spinacia oleracea*)	2.17
Green beans (*Phaseolus vulgaris*)	2.18
Celery (*Apium graveolens*)	2.19
Flowers	2.20
Commercial horticulture	2.21
Cover/Catch crop	2.22
Fodder radish cover/catch crop	2.22.1
Lucerne cover/catch crop	2.22.2
Grass cover/catch crop	2.22.3
Mustard cover/catch crop	2.22.4
Buckwheat cover/catch crop	2.22.5
Mixed crops for silage	2.22.6
Forage crop (for livestock grazing)	2.23

Habitat	Code
Lucerne or alfalfa (*Medicago sativa*)	2.24
Clover (*Trifolium* spp.)	2.25
Rotational grassland < 5 years old – unknown establishment	2.26
Rotational grassland < 5 years old – established through undersowing	2.26.1
Rotational grassland < 5 years old – direct drilled	2.26.2
Interrupted grassland (refreshed annually)	2.27
Grass crop grown for seed <40cm	2.28.1
Grass crop grown for seed >= 40cm	2.28.2
Grass crop grown for energy <40cm	2.28.3
Grass crop grown for energy >= 40cm	2.28.4
Cabbage (red or another colour, *Brassica oleracea*)	2.29
Poppies (as a crop, *Papaver spp.*)	2.30
Onions (*Allium spp*.)	2.31
Chicory (as a root crop, *Cichorium intybus* var. *sativum*)	2.32
Radish (*Raphanus raphanistrum subsp. sativus*)	2.33
Courgette (*Cucurbita pepo subsp. pepo*)	2.34
Carrot (*Daucus carota subsp. sativus*)	2.35
White mustard (*Brassica alba*)	2.36
Summer fallow (bare)	2.37
Winter sown Linseed (*Linum usitatissimum*)	2.38.1
Spring sown Linseed (*Linum usitatissimum*)	2.38.2
Soybeans (*Glycine max*)	2.39
Turnips (*Brassica rapa*)	2.40
Integrated Cropping (Trial)	2.41
Parsnips (*Pastinaca sativa*)	2.42
Lupins (*Lupinus spp.*)	2.43
Perennial herbaceous crops	
Rotational grassland >5 years old	3.1
Permanent grassland (Monoculture)	3.2
Permanent grassland (Downland etc.)	3.3
Permanent grassland (Ek2 low input)	3.4
Permanent grassland (Ek3 v. low input)	3.5
Permanent grassland (HLS – seasonally flooded for waders)	3.6
Perennial woody crops	
Orchard	4.1
Tree & shrub nursery	4.2
Coniferous plantation	4.3
Agroforestry Plantation	4.4

HABITAT	Code
Urban areas	
Urban area, % of green area in element <25%	5.1
Urban area, % of green area in element 26 to 50%	5.2
Urban area, % of green area in element 51 to 75%	5.3
Urban area, % of green area in element >75%	5.4
Water features	
Water courses (rivers)	6.1.1
Water courses (streams)	6.1.2
Water courses (canals)	6.1.3
Water courses (ditches >1.5m wide)	6.1.4
Water courses (ditches <1.5m wide)	6.1.5
Water courses (seasonal)	6.1.6
Water courses (with reeds)	6.1.7
Lakes and ponds	6.2
Reed Bed	6.2.1
Riverbank/ditchbank – linear element	6.3
Dyke	6.4
Wooded Dyke	6.4.1
Non-Habitat	
Road paved	7.1
Farmland track, unpaved	7.2
Farmland track (dirt/green)	7.2.1
Footpath	7.3
Railway	7.4
Other	7.5
Barnyard	7.6
Sterile strips	7.7

Table A1-2. Management codes for a) orchards; b) & c) grasslands; and d) funding.

a) Orchards

	Code
Low-stem intensive	1
High-stem Orchard	2

b) Grasslands: permanent versus rotational

Main management	Code
Permanent	1
Rotational – unknown establishment	2
Rotational - direct drill	2.1
Rotational - undersown	2.2

c) Grasslands, management

Management	Code
Mown	1
Grazed	2
Hay-cut	3
Multiple systems	4

d) Funding of habitat

Funding	Code
Scheme	1
No Scheme	2
PARTRIDGE Measure	3

Table A1-3: Column names and codes to be used in the attribute table for habitat mapping.

Column Name	**Codes to be used in column**	**Note**	**Data type**
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Small Integer
SEASON			Text
ELEMENTNR	1,2,3,4,5,6..X	This is the number that you designated to your elements during mapping	Small Integer
HABITAT	Use codes from Table A1-1		Text
LINWID	No code, a numerical width estimate	Estimated width of linear SNH in metres	Float
LINHGT	No code, a numerical height estimate	Estimated height of linear SNH in metres	Float
AREHGT	No code, a numerical height estimate	Estimated height of areal SNH in metres	Float
WATWID	No code, a numerical width estimate	Estimated width of water courses in metres	Float
ORCHTYP	1 = low-stem 2 = high-stem	See Table A1-2, a)	Small Integer
GRASSTYP	1 = Permanent 2 = Rotational (unknown establishment 2.1 = Rotational (direct drill) 2.2 = Rotational (undersown)	See Table A1-2, b)	Small Integer

Column Name	Codes to be used in column	Note	Data type
GRASSMAN	1 = Mown 2 = Grazed 3 = Hay-cut 4 = Multiple systems	See Table A1-2, c)	Small Integer
FUND	1 = Scheme 2 = No Scheme 3 = PARTRIDGE Measure	See Table A1-2, d)	Small Integer
REMARKS			Text
AREA	(hectares)	Needs to be generated in GIS	Geometry
LENGTH	(metres)	Needs to be generated in GIS	Geometry

Need to record type of mix in REMARKS in Table A1-3. – i.e. Goettinger etc.

Table A1-4: Codes to be used for the country and the sites.

COUNTRY	COUNTRY CODE	SITE	SITE CODE
ENGLAND	EN	ROTHERFIELD	ROTH
		LODDINGTON	LODD
		CHERITON	CHER
		HORNINGHOLD	HORN
SCOTLAND	SC	BALGONIE	BALG
		WHITBURGH	WHIT
		BALBIRNIE	BALB
		LENNOXLOVE	LENN
NETHERLANDS	NL	BURGH-SLUIS	BURG
		OUDE DOORN	OUDD
		GENDEREN	GEND
		NIEUWERKERKE	NIEU
GERMANY	DE	DIEMARDEN	DIEM
		NESSELRÖDEN	NESS
		BILSHAUSEN	BILS
		RITTMARSHAUSEN	RITT
BELGIUM	BE	ISABELLAPOLDER	ISAB
		RAMSKAPELLE	RAMS
		MIDDELKERKE	MIDD
		OUDEMANSPOLDER	OUDM

Table A1-5: Column names and codes to be used in the attribute table for mapping outlines of areas.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Small Integer
Area	(hectares)	Needs to be generated in GIS	Geometry

Table A1-6. Monitoring hares through transects.

a. Column names and codes to be used in the attribute table for hare transects digitised as polylines.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITE	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
TRANSECT_N		Transect number	Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
DATE	Dd/mm/jjjj		Date
LENGTH	(Kilometres)	Needs to be generated in GIS	Geometry
REMARKS			Text

b. Column names and codes to be used in the attribute table for hare transect viewsheds digitised as polygons.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITE	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
TRANSECT_N		Transect number	Integer
AREA	(hectares)	Needs to be generated in GIS	Geometry
REMARKS			Text

c. Column names and codes to be used in the attribute table for hare counts – will need to discuss how best to do this.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITE	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Short integer
TRANSECT_N			Short integer
YEAR			Integer
DATE	Format: dd/mm/yyyy		Date
TIME	hh:mm	Time of observation	Text
OBSERV_N	1, 2, 3, 4, …	First, second, third, etc. observation of that session	Short integer
SPECIES		Write down full name	Text
NUMBER		Number of animals	Short integer
REMARKS			Text

Table A1-7. Monitoring hares through viewpoint counts.

a. Column names and codes to be used in the attribute table for mapping viewpoints used to monitor hare numbers, digitised as points representing the location used to view the field being monitored.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITE	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
POINT_N		Give every viewpoint a number. Be consistent.	Short integer
YEAR			Integer
LENGTH	(kilometres)	Needs to be generated in GIS	Geometry
REMARKS			Text

b. Column names and codes to be used in the attribute table mapping viewsheds in hare recording, digitised as polygons and reflecting the area of the field where it is possible to see hares from the viewpoint.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITE	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR		Record the year as integer	Integer
POINT_N		Viewpoint number	Integer
AREA	(hectares)	Needs to be generated in GIS	Geometry
REMARKS			Text

c. Column names and codes to be used in the attribute table for mapping the number of hares recorded from a viewpoint, digitised as points and reflecting the centroid of the viewsheds – see b. above.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITE	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Short integer
TRANSECT_N		Viewpoint number but this is easier to combine with transect counts in analysis	Short integer
YEAR			Integer
DATE	Format: dd/mm/yyyy		Date
TIME	hh:mm	Time of observation	Text
OBSERV_N	1, 2, 3, 4, ...	First, second, third, etc. observation of that session	Short integer
SPECIES		Write down full name	Text
NUMBER		Number of animals	Short integer
REMARKS			Text

Table A1-8. Monitoring farmland birds through transects.

a. Column names and codes to be used in the attribute table for farmland bird transects digitised as polylines. – needs to reflect data from AVIMAP.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
DATE	Record the date the count was done		Date
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
ID			Text
DISTANCE	(Kilometres)	Needs to be generated in GIS	Geometry

b. Column names and codes to be used in the attribute table for farmland bird locations digitised as points.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
DATE	Record the date the count was done		Date
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
Species			Text
Number			Small Integer
Sex	Unknown, Male, Female, Pair		Text
Breeding Code			Small Integer
Remark		Comment field	Text

Table A1-9. Monitoring grey partridges with playback.

a. Column names and codes to be used in the attribute table for recording the individual transects walked for grey partridge counts done using playback, digitised as polyline.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
DATE		Record the date the count was done	Day
STARTTIME		The time the count was started	Time
ENDTIME		The time the count was finished	Time
RECORDER		Initials of the observer	Text
ID			Text
DISTANCE		Needs to be generated in GIS	Geometry
COUNTNUM	Combination of date, observer to id counting session.		Text

b. Column names and codes to be used in the attribute table for recording the individual grey partridge recorded for each session, to be recorded as points.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
ID			Text
TYPE	PAIR, SINGLE, UNKNOWN		Text
COUNTNUM	Combination of date, observer to id counting session.		Text

c. Column names and codes to be used in the attribute table for summary transects for grey partridge counts done using playback digitised as polyline.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
ID			Text
DISTANCE	(Kilometres)	Needs to be generated in GIS	Geometry

d. Column names and codes to be used in the attribute table for recording the summary of the grey partridges recorded, to be recorded as points.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
ID			Text
DISTANCE	(Kilometres)	Needs to be generated in GIS	Geometry

Table A1-10. Monitoring grey partridge pairs through area counts.

a. Column names and codes to be used in the attribute table for mapping the area monitored for grey partridge pairs from each individual counting session, digitised as polygons.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
DATE		Record the date the count was done	Day
STARTTIME		The time the count was started	Time
ENDTIME		The time the count was finished	Time
RECORDER		Initials of the observer(s)	Text
AREA	(hectares)	Needs to be generated in GIS	Geometry
COUNTNUM	Combination of date, observer to id counting session.		Text

b. Column names and codes to be used in the attribute table for mapping grey partridge pairs from each individual counting session, digitised as points.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
TYPE	PAIR, SINGLE		Text
COUNTNUM	Combination of date, observer to id counting session.		Text

c. Column names and codes to be used in the attribute table for mapping the area monitored for the summary of grey partridge pairs, digitised as polygons.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference		Small Integer

	2 = Demo		
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
AREA	(hectares)	Needs to be generated in GIS	Geometry

d. Column names and codes to be used in the attribute table for mapping the summary of grey partridge pairs, digitised as points.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
TYPE	PAIR, SINGLE		Text

Table A1-11. Monitoring grey partridge coveys through area stubble counts.

a. Column names and codes to be used in the attribute table for mapping the area monitored for grey partridge pairs from each individual counting session, digitised as polygons.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
DATE		Record the date the count was done	Day
STARTTIME		The time the count was started	Time
ENDTIME		The time the count was finished	Time
RECORDER		Initials of the observer(s)	Text
AREA	(hectares)	Needs to be generated in GIS	Geometry
COUNTNUM	Combination of date, observer to id counting session.		Text

b. Column names and codes to be used in the attribute table for mapping the results from each session of grey partridge covey stubble count, digitised as points.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
MALES			Integer
FEMALES			Integer
YOUNG			Integer
UNSEXED			Integer
UNAGED_UNSEXED			Integer
SPR_PRS_CALC		Number of males in a covey plus an “extra” females	Integer
COUNTNUM	Combination of date, observer to id counting session.		Text

c. Column names and codes to be used in the attribute table for mapping the area monitored for the summary of grey partridge pairs, digitised as polygons.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
AREA	(hectares)	Needs to be generated in GIS	Geometry

d. Column names and codes to be used in the attribute table for mapping the summary of grey partridge covey stubble counts, digitised as points.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
MALES			Integer
FEMALES			Integer
YOUNG			Integer
UNSEXED			Integer
UNAGED_UNSEXED			Integer
SPR_PRS_CALC		Number of males in a covey plus any "extra" females. If no adults then we need to look at that covey.	Integer

Table A1-12. Mapping feeder locations.

a. Column names and codes to be used in the attribute table for mapping feeders, digitised as points.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
ID	Number of feeder	Number the feeders from 1 to x.	Integer
STARTDATE		Date first filled	Date
ENDDATE		Date last filled	Date
TYPE			Text
FEED			Text

Table A1-13. Mapping snare/trap locations.

a. Column names and codes to be used in the attribute table for mapping snares, traps etc., digitised as points.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
ID	Number of snare	Number the snares from 1 to x.	Integer
STARTDATE		Date first set	Date
ENDDATE		Date last set	Date
TYPE			Text

Table A1-14. Mapping locations of fences used to protect nests etc.

a. Column names and codes to be used in the attribute table for fences used to exclude predators around nests, etc. digitised as polyline.

Column Name	Codes to be used in column	Note	Data type
COUNTRY	See Table A1-4 for codes		Text
SITES	See Table A1-4 for codes		Text
TYPE	1 = Reference 2 = Demo		Small Integer
YEAR	2017,2018,2019,2020	Record the year as integer	Integer
ID			Text
LENGTH	(Metres)	Needs to be generated in GIS - metres	Geometry

Table A1-15: List of Proposed Shapefiles.

Name of shapefile	Description	Type of data	Attribute structure
Habitat_mapping_CCCC_SEA_YR	Habitat mapped on a per season basis	Polygon	Table A1-3
Outline_CCCC_SEA_YR	Outlines of areas	Polygon	Table A1-5
Hare_transects_CCCC_YR	Hare transects	Polyline	Table A1-6a
Hare_tran_viewsheds_CCCC_YR	Hare transect viewsheds	Polygon	Table A1-6b
	May need one for the hare count if different structure than above		
Hare_viewpoint_CCCC_YR	Hare viewpoint	Point	Table A1-7a
Hare_vwpt_viewsheds_CCCC_YR	Hare viewpoint viewsheds	Polygon	Table A1-7b
Hare_cent_viewsheds_CCCC_YR	Centroid of the Hare viewsheds – hare numbers	Point	Table A1-7c

Name of shapefile	Description	Type of data	Attribute structure
Fbird_transects_CCCC_YR	Farmland bird transects	Polyline	Table A1-8a
Fbird_CCCC_YR	Farmland bird locations	Point	Table A1-8b
GP_playbk_ind_trscts_CCCC_YR	Individual transects grey partridge playback	Polyline	Table A1-9a
GP_playbk_ind_cnts_CCCC_YR	Counts from individual transects grey partridge playback	Point	Table A1-9b
GP_playbk_sum_trscts_CCCC_YR	Summary transects grey partridge playback	Polyline	Table A1-9c
GP_playbk_sum_cnts_CCCC_YR	Counts from summary transects grey partridge playback	Point	Table A1-9d
GP_spr_ind_area_CCCC_YR	Individual spring count areas of grey partridge using area counting	Polygon	Table A1-10a
GP_spr_ind_cnts_CCCC_YR	Individual spring counts of grey partridge using area counting	Point	Table A1-10b
GP_spr_sum_area_CCCC_YR	Summary spring count areas of grey partridge using area counting	Polygon	Table A1-10c
GP_spr_sum_cnts_CCCC_YR	Summary spring counts of grey partridge using area counting	Point	Table A1-10d
GP_aut_ind_area_CCCC_YR	Individual autumn count areas of grey partridge using area counting	Polygon	Table A1-11a
GP_aut_ind_cnts_CCCC_YR	Individual autumn counts of grey partridge using area counting	Point	Table A1-11b
GP_aut_sum_area_CCCC_YR	Summary autumn count areas of grey partridge using area counting	Polygon	Table A1-11c
GP_aut_sum_cnts_CCCC_YR	Summary autumn counts of grey partridge using area counting	Point	Table A1-11d
Feeder_CCCC_YR	Feeder locations	Point	Table A1-12
Snare_trap_CCCC_YR	Snare/trap locations	Point	Table A1-13
Protective_fence_CCCC_YR	Locations of fences to protect nests	Polyline	Table A1-14

Possible data files if deemed appropriate after discussion

Name of shapefile	Description	Type of data	Attribute structure
Fence_CCCC_SEA_YR	Fences	Polyline	TBC
Gate_CCCC_SEA_YR	Gates	Point	TBC

CCCC = code for sites, see Table A1-4; SEA = season – Winter and Summer – reflecting hare counts and grey partridge chick hatching; YR = year for example “17” = 2017Appendix 1: Recording Sheets and additional information for the field habitat mapping

Habitat Recording Sheet

Observers		Date	
Site		Country	

Elem-ent Nr.	Habitat Type	Width WL	Height WL	Height WA	Width Water element	Grassland Permanent /Rotational	Grass-land Manage-ment	Orchard Manage-ment	How Funded
[redacted]									

Minimum Mapping Unit (MMU)

The minimum mapping unit (MMU) definitions are as follows:

- Any element (SNH, EWH, crop, urban area, water body) selected for mapping in the landscape sector needs to have a minimum surface area of $100m^2$, to guarantee a minimum impact on the indicators. If there are obvious features that cannot be combined with other features surrounding them that covers less than $100m^2$, these can be added as polygons but do not sub-divide habitats unnecessarily.
- SNH & EWH Linear Elements (WL, HL) should have a minimum width of 1.5m and a maximum width of <25m. They must be at least 50m in length.
- SNH & EWH Areal Elements (WA, HA, FA) should be at least 25m wide and at least 50m in length.
- The remaining elements (crops, water bodies, urban areas) must be a minimum width of 1.5m and at least 50m in length.

Scoring criteria

Code	Name	Nesting Habitat			Brood-rearing			Overwinter Cover		
		Good Quality	High Quality	Notes	Good Quality	High Quality	Notes	Escape Cover	Forage Cover	Notes
1.2	WL: woody linear elements (UNSPECIFIED)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.						
1.2.1	WL: new hedge (< 5 years old)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.					X	
1.2.2	WL: dense wide hedge (>3m) with no or very few trees (max 1 per 100m) and suitable grass margin for nesting, height max 5m	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.						
1.2.3	WL: narrow hedge (<3m) with no or little ground cover (winter cover) but suitable nesting cover	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.					X	
1.2.7	WL: woody point elements (bunches of brambles, shrubs)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.				X	X	

Code	Name	Good Quality	High Quality	Notes	Good Quality	High Quality	Notes	Escape Cover	Forage Cover	Notes
1.2.8	WL: woody area elements (extensive grassland with some shrubs)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.				X	X	
1.4.1	HL: herbaceous linear elements (field boundary)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.				X	X	
1.4.2	HL: herbaceous linear elements (buffer strip)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.						
1.4.3	HL: herbaceous linear elements (ditchside)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.					X	
1.6	Beetle banks – linear element	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.					X	
1.7.1	Conservation headlands – linear element				X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.			

Code	Name	Good Quality	High Quality	Notes	Good Quality	High Quality	Notes	Escape Cover	Forage Cover	Notes
1.7.2	Unharvested crop (Vogelacker) – areal element				X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X	X	
1.7.3	Cultivated uncropped margin or arable margin - linear				X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.			
1.7.4	Unharvested crop – linear element							X	X	
1.8	Floristically enhanced grass margin (cut after 1 August)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.			
1.8.1	Floristically enhanced grass margin (cut before 1 August)	X			X					
1.8.1.1	Floristically enhanced grass margin (partially cut after 1 August)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.			
1.8.1.2	Floristically enhanced grass margin (partially cut before 1 August)	X			X					

Code	Name	Good Quality	High Quality	Notes	Good Quality	High Quality	Notes	Escape Cover	Forage Cover	Notes
1.8.2	Grass margin (partially cut after 1 August) – linear element	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X					
1.8.3	Grass margin (partially cut before 1 August) – linear element	X			X					
1.8.4	Grass margin (entirely cut after 1 August) – linear element	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X					
1.8.5	Grass margin (entirely cut before 1 August) – linear element	X			X					
1.8.6	Grass margin (partially cut after 1st August) – Areal element (>15m wide)	X			X					
1.8.6.1	Grass feature (cut after 1st August) – Areal element (>15m wide, floristically diverse)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.			
1.8.6.2	Grass feature (cut before 1st August) – Areal element (>15m wide, floristically diverse)	X			X					

Code	Name	Good Quality	High Quality	Notes	Good Quality	High Quality	Notes	Escape Cover	Forage Cover	Notes
1.8.7	Floristically enhanced meadow	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.			
1.8.8	Floristically enhanced meadow-cut	X			X					
1.8.9	Floristically enhanced grass meadow (>8m, cut after 1st August)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.			
1.8.10	Floristically enhanced grass meadow (>8m, cut before 1st August)	X			X					
1.9.1	Wild-bird cover in first year – linear element (< 15m wide)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X	X	
1.9.2	Wild-bird cover in second year – linear element (< 15m wide)	X		Good Quality if not too dense.	X		Good Quality if not too dense.	X	X	
1.9.3	Wild-bird cover older than 2nd year – linear element (< 15m)	X		Good Quality if not too dense.	X		Good Quality if not too dense.	X	X	

Code	Name	Good Quality	High Quality	Notes	Good Quality	High Quality	Notes	Escape Cover	Forage Cover	Notes
1.9.4	Wild-bird cover in first year – areal elements (> 15m wide)	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X	X	
1.9.5	Wild-bird cover in second year – (>15m wide)	X		Good Quality if not too dense.	X		Good Quality if not too dense.	X	X	
1.9.6	Wild-bird cover older than 2nd year – (> 15m)	X		Good Quality if not too dense.	X		Good Quality if not too dense.	X	X	
1.10.1	Pollen & Nectar Mix in first year – linear element				X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.		X	
1.10.2	Pollen & Nectar Mix older than 1st year – linear element	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.		X	
1.10.3	Pollen & Nectar Mix in first year – areal element				X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.		X	
1.10.4	Pollen & Nectar Mix older than first year – areal element	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.	X	X	High Quality if features are greater than 15m wide or if adequate predator control on site. Otherwise, only Good Quality.		X	

Code	Name	Good Quality	High Quality	Notes	Good Quality	High Quality	Notes	Escape Cover	Forage Cover	Notes
1.11.2	Winter stubbles – naturally weedy							X	X	Escape and Forage Cover if within 10m of hedges of wild-bird mixes. Otherwise, only Forage Cover.
1.11.3	Winter stubbles – enhanced with seed mix							X	X	Escape and Forage Cover if within 10m of hedges of wild-bird mixes. Otherwise, only Forage Cover.
1.12.1	Extended overwintered stubbles – naturally weedy		X			X		X	X	Escape and Forage Cover if within 10m of hedges of wild-bird mixes. Otherwise, only Forage Cover.
1.12.2	Extended overwintered stubbles – enhanced with seed mix		X			X		X	X	Escape and Forage Cover if within 10m of hedges of wild-bird mixes. Otherwise, only Forage Cover.
1.14	Field corners	X								
2.1.3	Winter cereal stubble (weedy)							X	X	Escape and Forage Cover if within 10m of hedges of wild-bird mixes. Otherwise, only Forage Cover.
2.1.5	Winter maize stubble (weedy)							X	X	Escape and Forage Cover if within 10m of hedges of wild-bird mixes. Otherwise, only Forage Cover.
2.2.1	Winter sown Wheat (Triticum aestivum & associated spp.)								X	
2.2.1.1	Winter sown Spelt (Triticum spelta & associated spp.)								X	
2.3.1	Winter sown Barley (Hordeum sativum)								X	
2.4.1	Winter sown Oats (Avena sativa)								X	

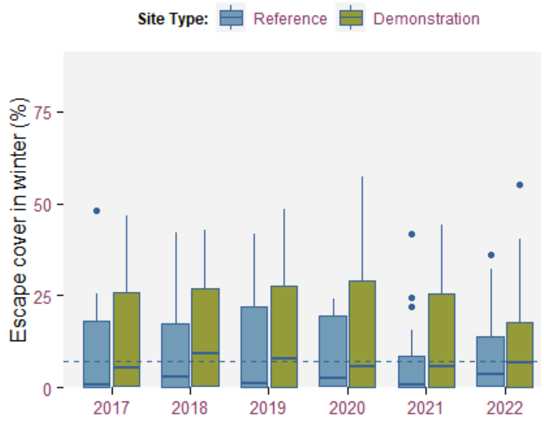
Code	Name	Good Quality	High Quality	Notes	Good Quality	High Quality	Notes	Escape Cover	Forage Cover	Notes
2.14.1	Winter sown Oilseed rape (Brassica spp. hybrid)							X	X	
2.22	Cover/Catch crop							X	X	
2.22.1	Fodder radish cover/catch crop							X	X	
2.29	Cabbage (red or another colour, Brassica oleracea)							X	X	
2.36	White mustard (Brassica alba)							X	X	
2.4	Turnips (Brassica rapa)							X	X	
3.3	Permanent grassland (Downland etc.)								X	

Appendix 2 – Non-significant results:

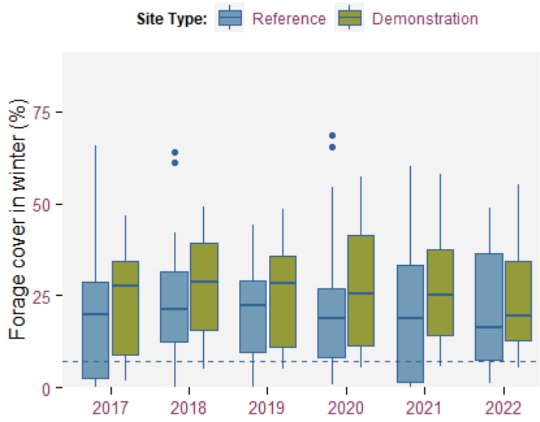
Composition

Beneficial habitat (%) for farmland birds

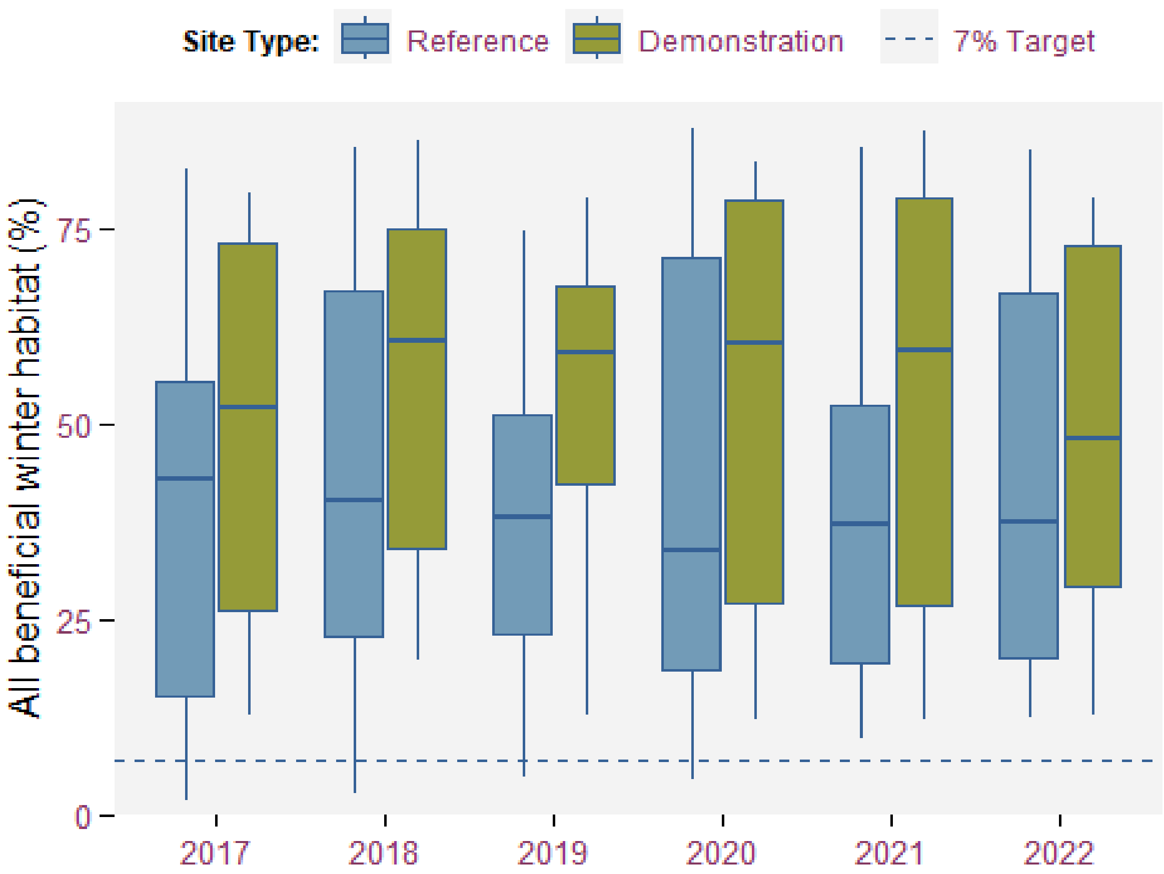
Winter habitat



(a) 'Escape cover' habitat.



(b) 'Forage cover' habitat.



(c) All beneficial winter habitat.

Figure A2-1: The percentage of demonstration and reference sites occupied by (a) escape cover, (b) forage cover and (c) all beneficial winter habitat combined over the six years of the PARTRIDGE project. The 7% target is provided for comparison.

There was no significant interaction between site type and year ($F_{(1, 98)}$ = 0.130, p = 0.721, Figure A2-1) in the percentage of project sites occupied by beneficial habitats in winter. We found no significant differences between the proportion of our demonstration and reference sites occupied by beneficial winter habitat ($F_{(1, 9)}$ = 4.80 p = 0.056).Likewise, there was no significant change in the proportion of sites occupied over time ($F_{(1, 98)}$ = 0.010, p = 0.941).

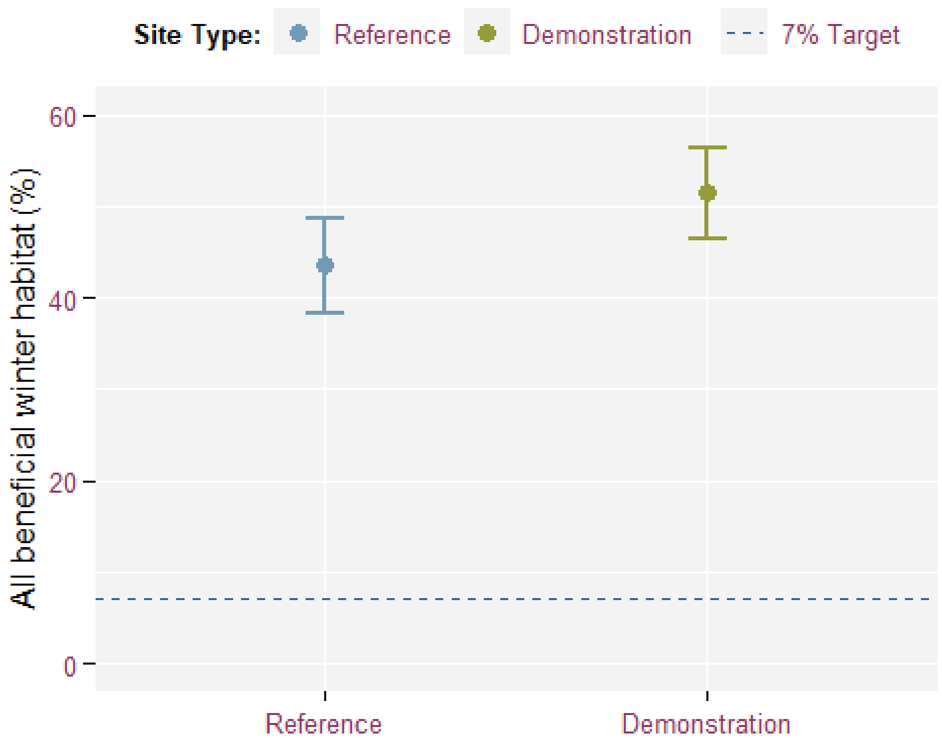


Figure A2-2: The average percentage of beneficial winter habitat (± standard error) on our demonstration and reference sites in the final three years of the PARTRIDGE project (2020 - 2022). The 7% target is provided for comparison.

Heterogeneity

Simpson's diversity

Beneficial habitat

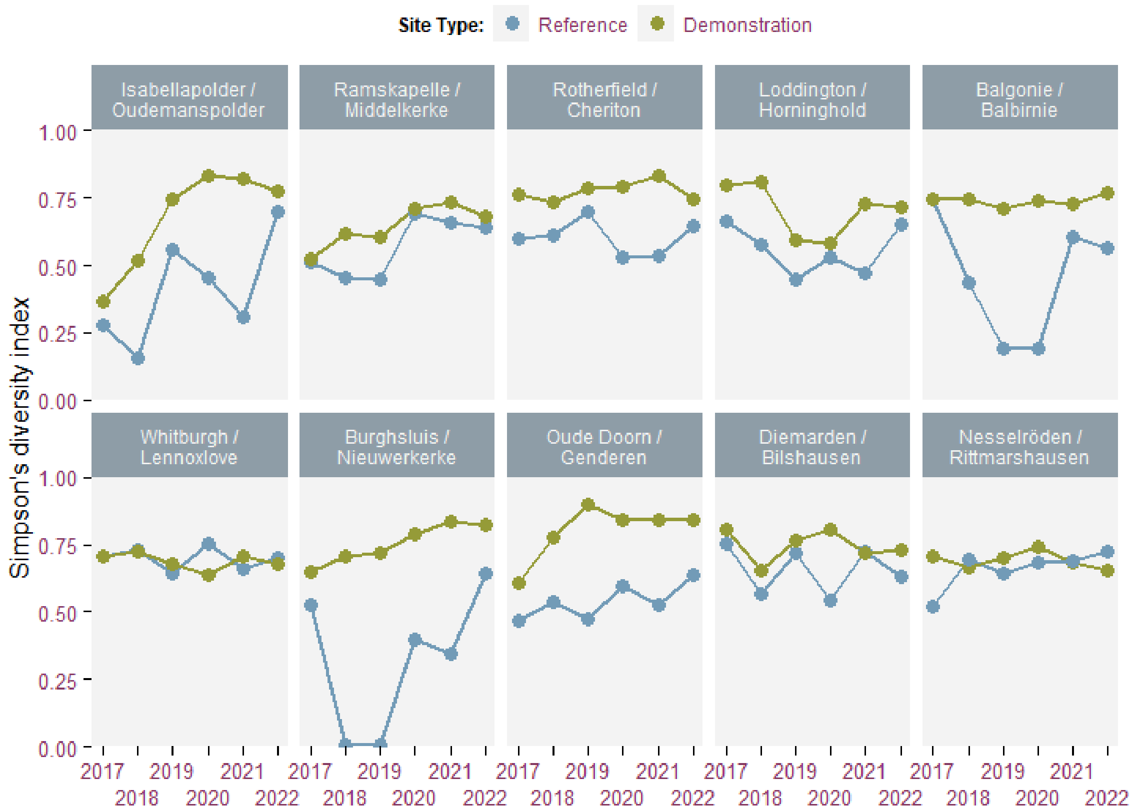


Figure A2-3: The Simpson's diversity index of beneficial winter habitat at demonstration and reference sites over the six years of the PARTRIDGE project.

There was no significant interaction between site type and time for the Simpson's diversity index of beneficial winter habitat ($F_{(1, 98)} = 0.83$, $p = 0.364$, Figure A2-3), nor were we able to detect a significant effect of site type on diversity ($F_{(1, 18)} = 6.11$, $p = 0.024$). There was no significant change through time ($F_{(1, 98)} = 3.47$, $p = 0.065$).

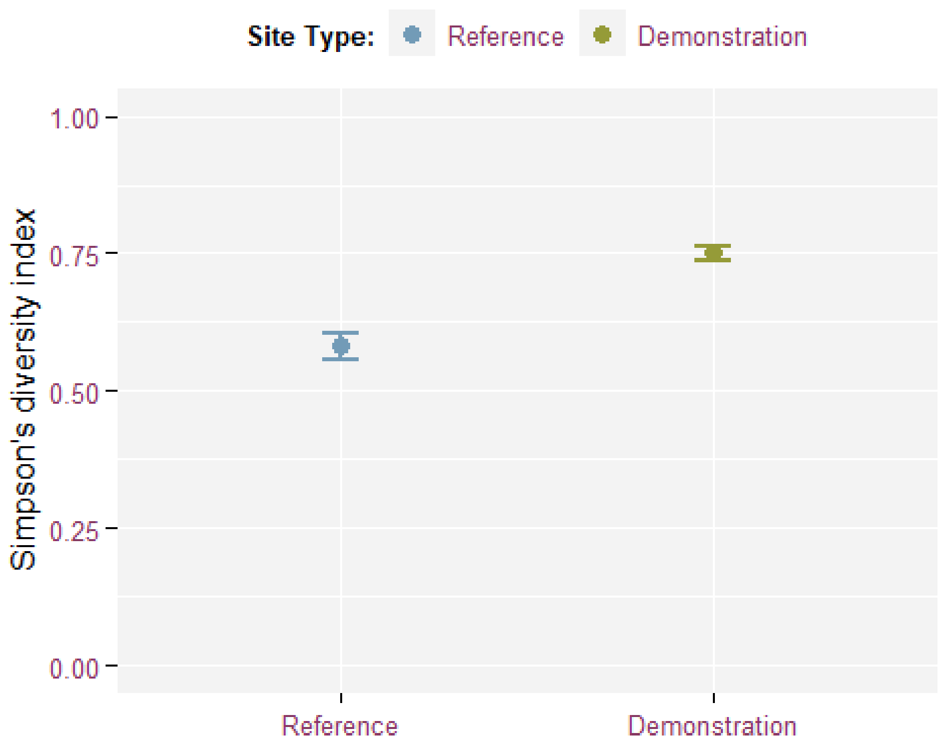


Figure A2-4: The average Simpson's diversity index (± standard error) of beneficial winter habitat at our demonstration and reference sites in the final three years of the PARTRIDGE project (2020 - 2022).

Crop habitat

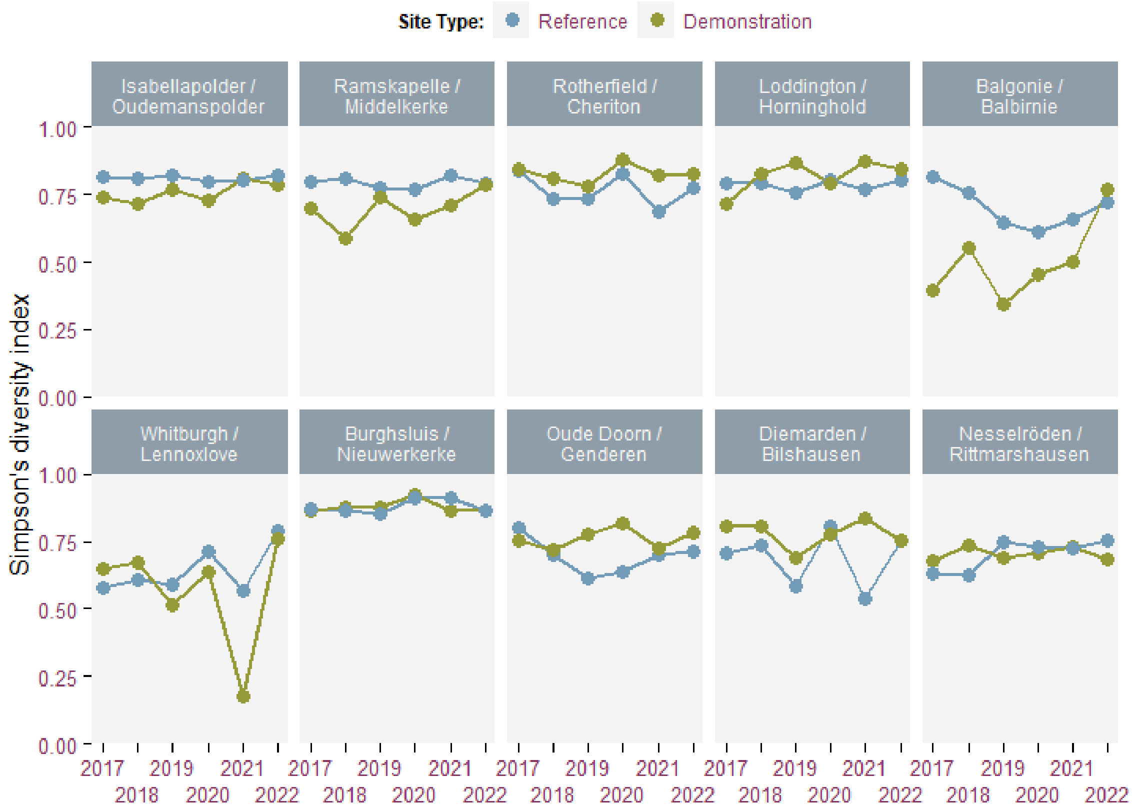


Figure A2-5: Changes in the Simpson's diversity index of summer cropping at demonstration and reference sites over the six years of the PARTRIDGE project.

We did not detect a significant interaction between time and site type when investigating the Simpson's diversity of summer crops at our project sites ($F_{(1, 98)}$ = 0.17, *p* = 0.680, Figure A2-5), nor did we detect a significant effect of site type on diversity ($F_{(1, 9)}$ = 0.730, *p* = 0.414). These values did not change significantly through time ($F_{(1, 98)}$ = 0.40, *p* = 0.528).

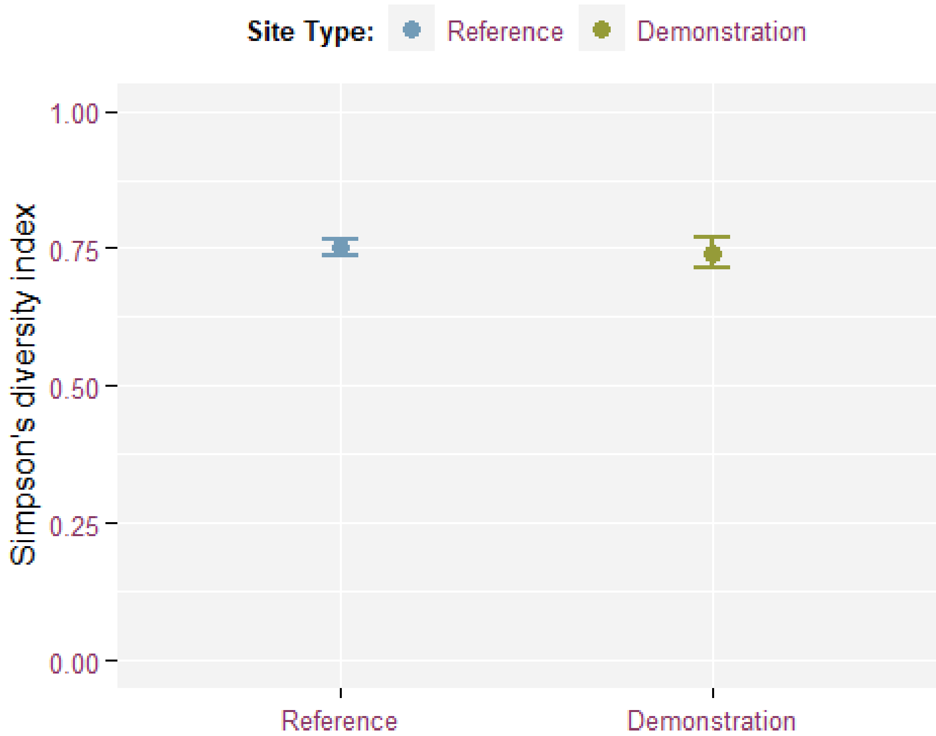


Figure A2-6: The average Simpson's diversity index (± standard error) of summer crops at our demonstration and reference sites in the final three years of the PARTRIDGE project (2020 - 2022).

Semi-natural habitat

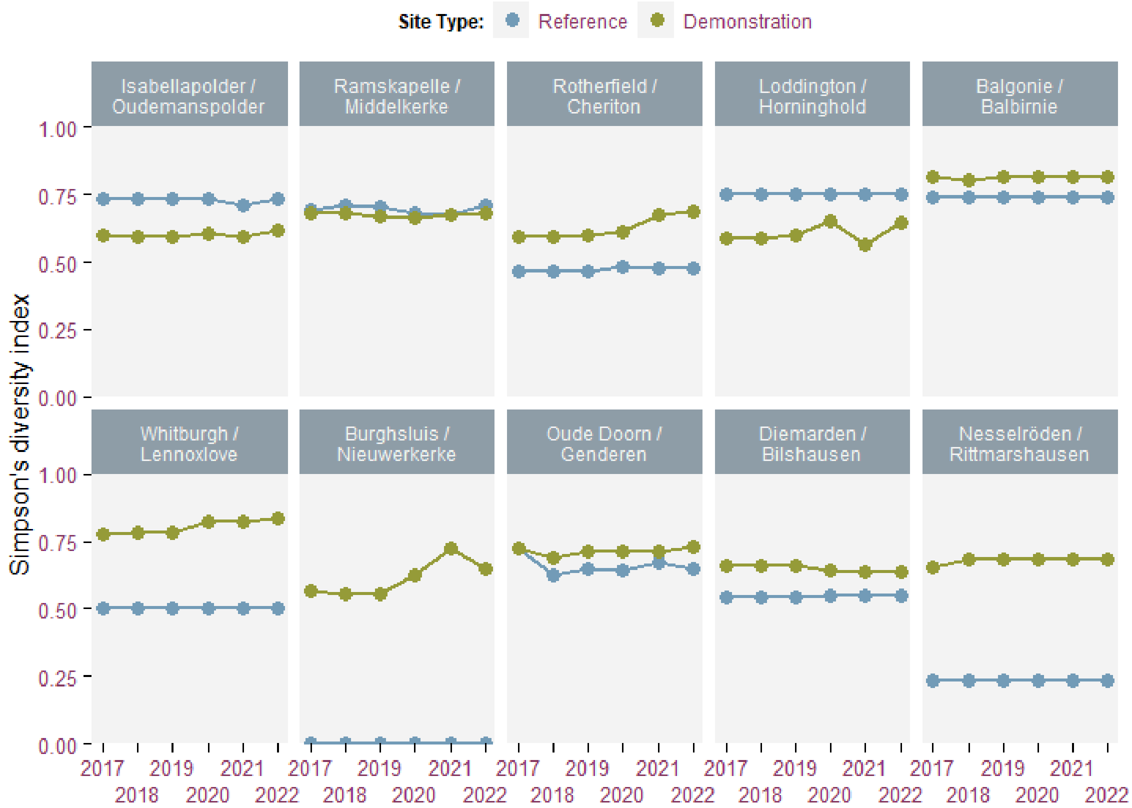


Figure A2-7: The Simpson's diversity index of semi-natural habitat at demonstration and reference sites over the six years of the PARTRIDGE project.

We were unable to test the significance of any effects between site type and time on the diversity index of semi-natural habitat at our project sites due to a lack of convergence in our models, likely due to the lack of variation in this index across the six years of the project.

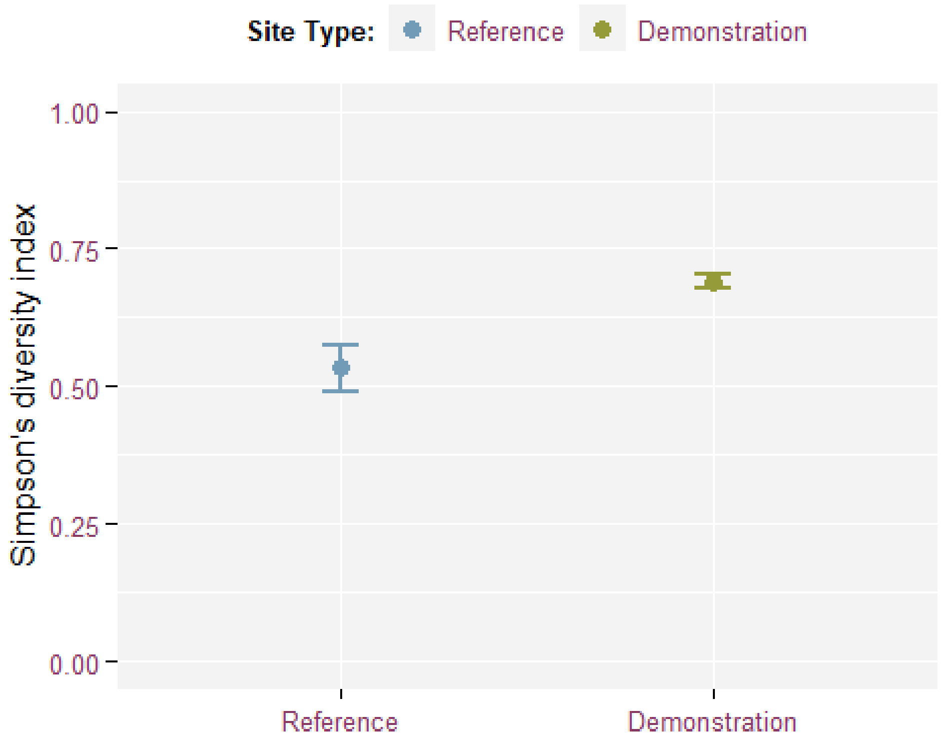


Figure A2-8: The average Simpson's diversity index of semi-natural habitat (± standard error) on our demonstration and reference sites in the final three years of the PARTRIDGE project (2020 - 2022).

Configuration

Landscape-level metrics

Aggregation index

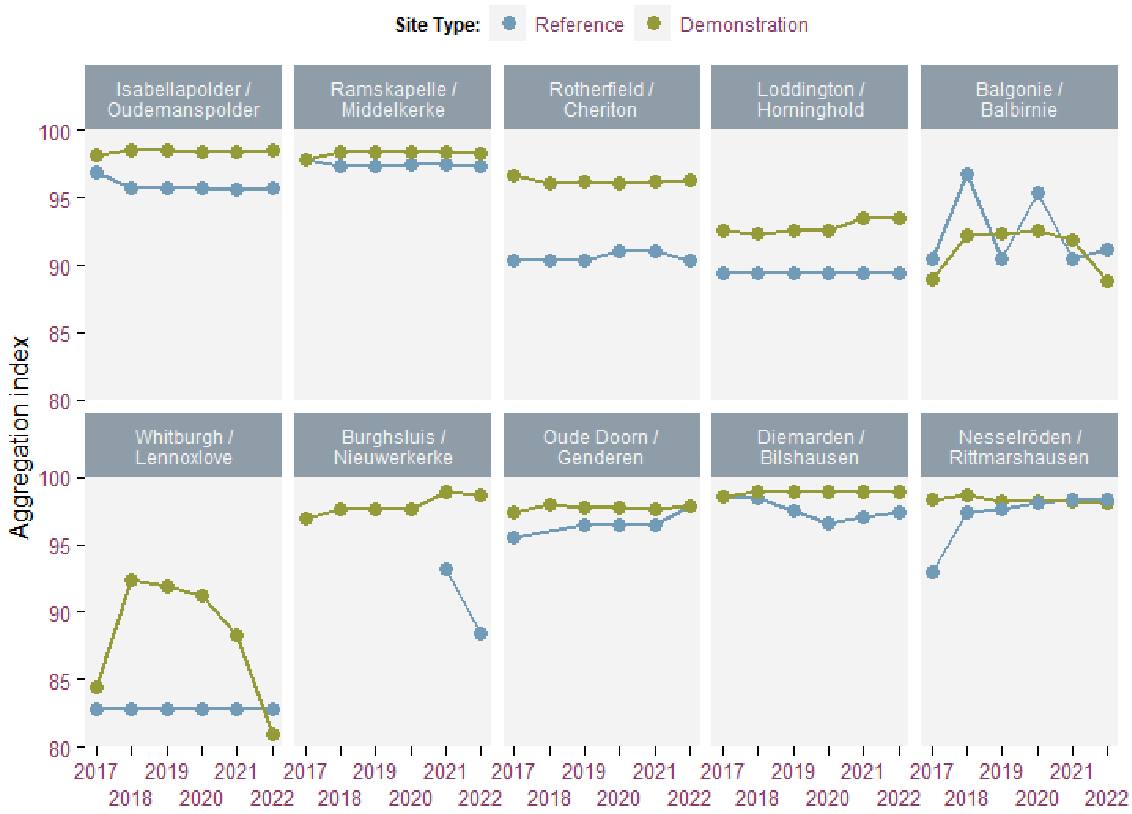


Figure A2-9: Changes over time in the aggregation index values of brood-rearing habitat at our project sites.

We were unable to detect a significant interaction between time and site type when considering the aggregation index of brood-rearing habitat ($F_{(1, 93.6)} = 0.07$, $p = 0.788$, Figure A2-9). Likewise, we were unable to find a significant effect of site type on these values ($F_{(1, 8.8)} = 10.32$, $p = 0.701$). There was no significant change in these values over time ($F_{(1.82, 16.41)} = 1.34$, $p = 0.702$).

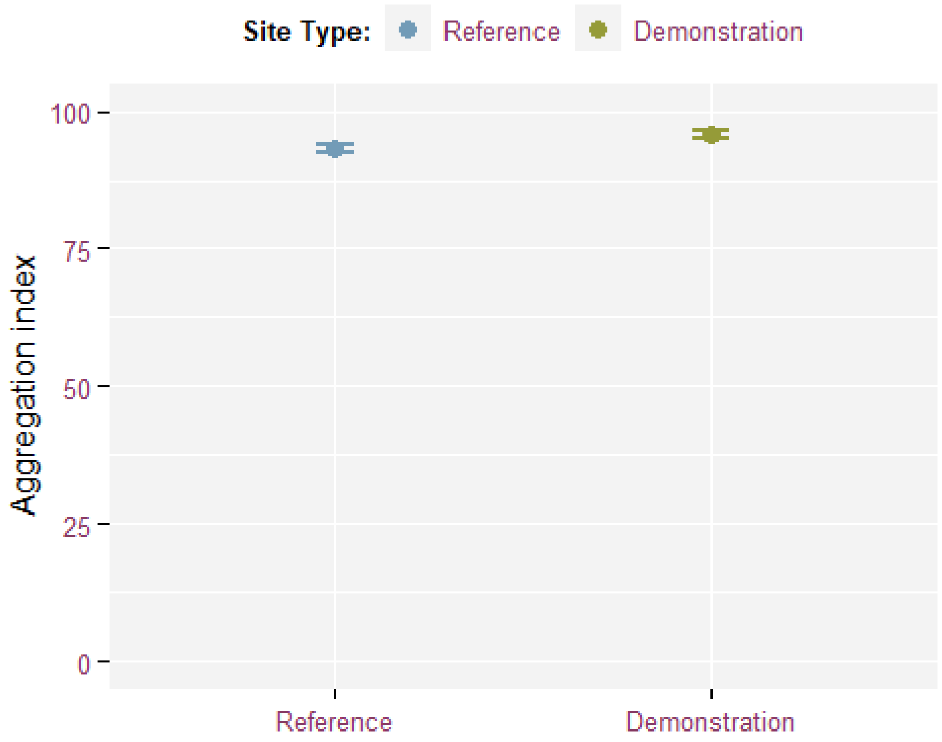


Figure A2-10: The difference in the aggregation index of brood-rearing habitat of our project sites in the final three years of the project (2020 - 2022).

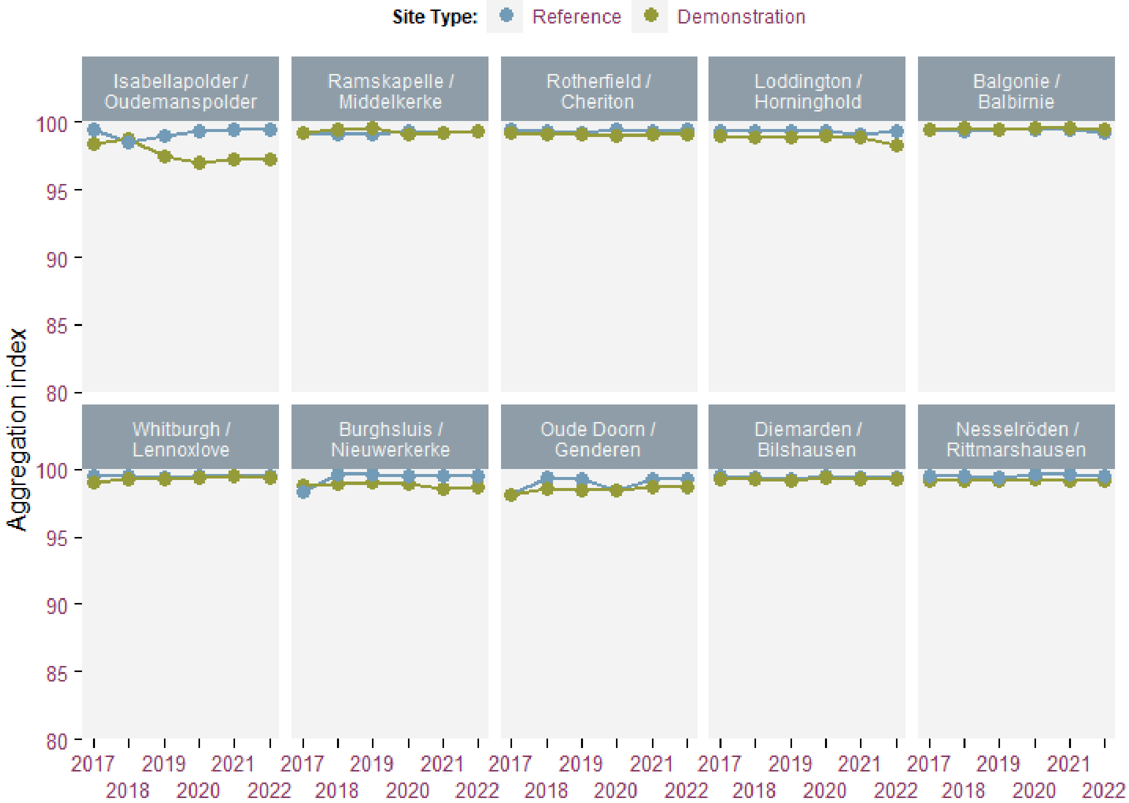


Figure A2-11: Changes over time in the aggregation index values of overwinter cover habitat at our project sites.

We were also unable to detect a significant interaction between site type and time when considering the aggregation index of overwinter cover habitat ($F_{(1.91, 17.18)}$ = 1.23, p = 0.632, Figure A2-11). The effect of site type on these values, was not significant ($F_{(1, 9)}$ = 6.86, p = 0.028. We did not detect a significant change in these values through time ($F_{(1, 98)}$ = 0.00, p = 0.994).

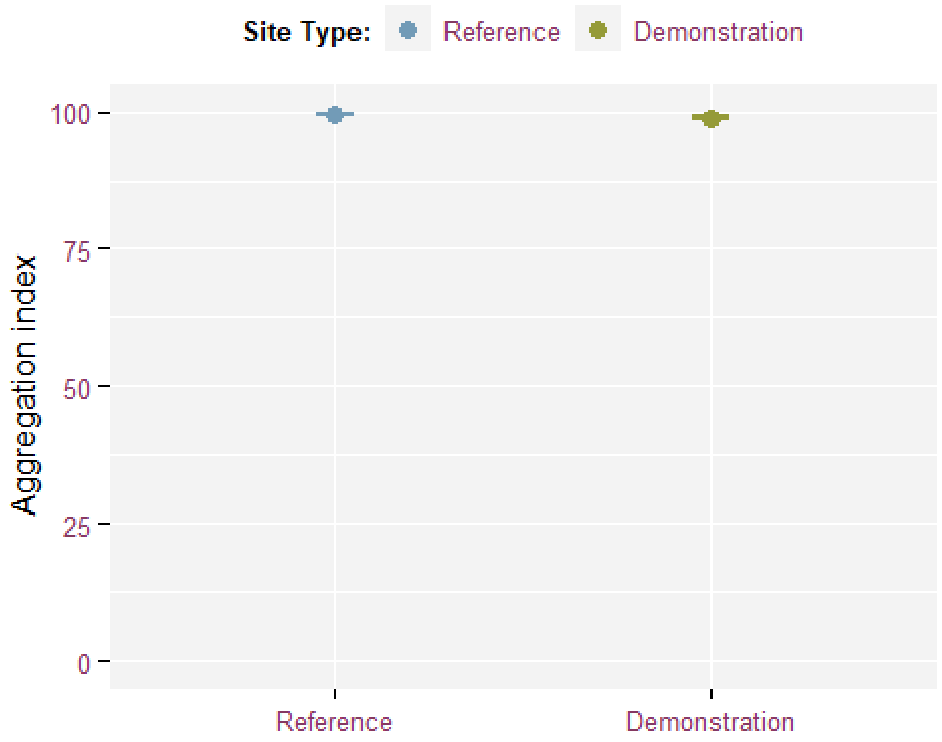


Figure A2-12: The difference in the aggregation index of overwinter cover habitat of our project sites in the final three years of the project (2020 - 2022).

Clumpiness index

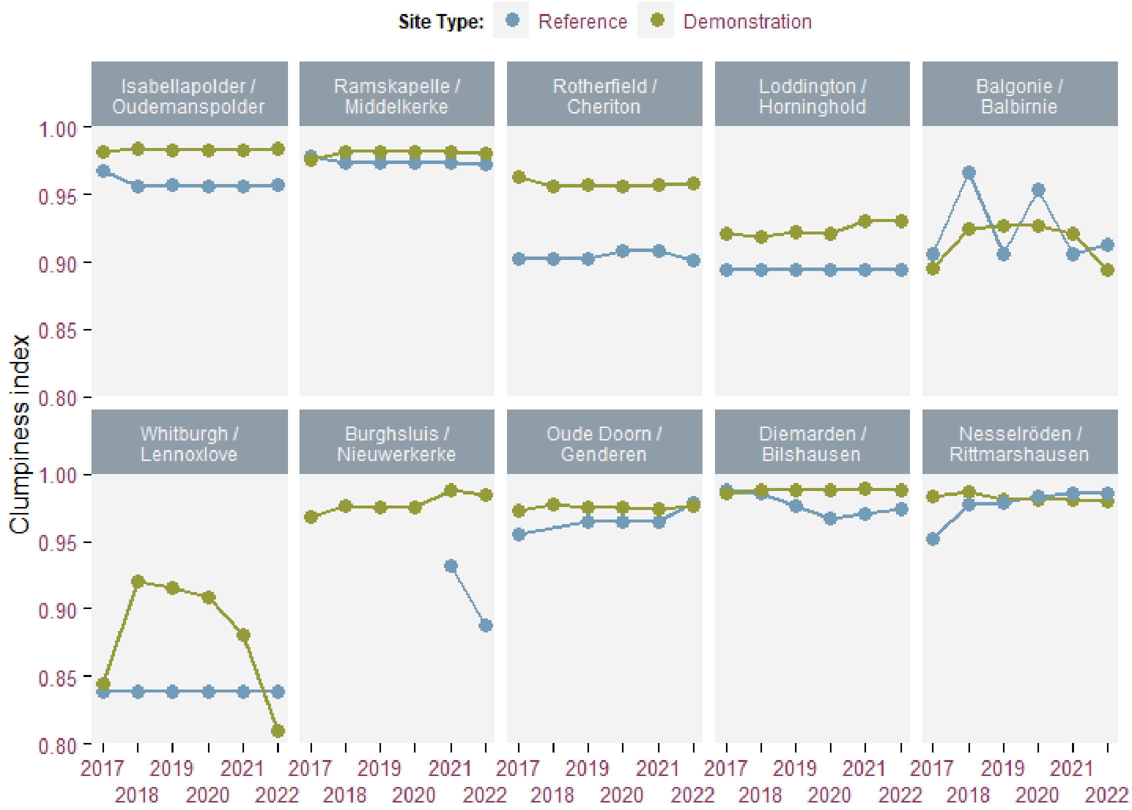


Figure A2-13: Changes over time in the clumpiness index of brood-rearing habitat at our project sites.

We found no significant interaction between time and site type on the clumpiness of brood-rearing habitat ($F_{(1, 93.5)}$ = 0.01, p = 0.916, Figure A2-13), nor did we find a significant effect of site type ($F_{(1, 8.8)}$ = 9.6, p = 0.013). We did not find a significant change in these values over time ($F_{(1, 93.5)}$ = 0.18, p = 0.668).

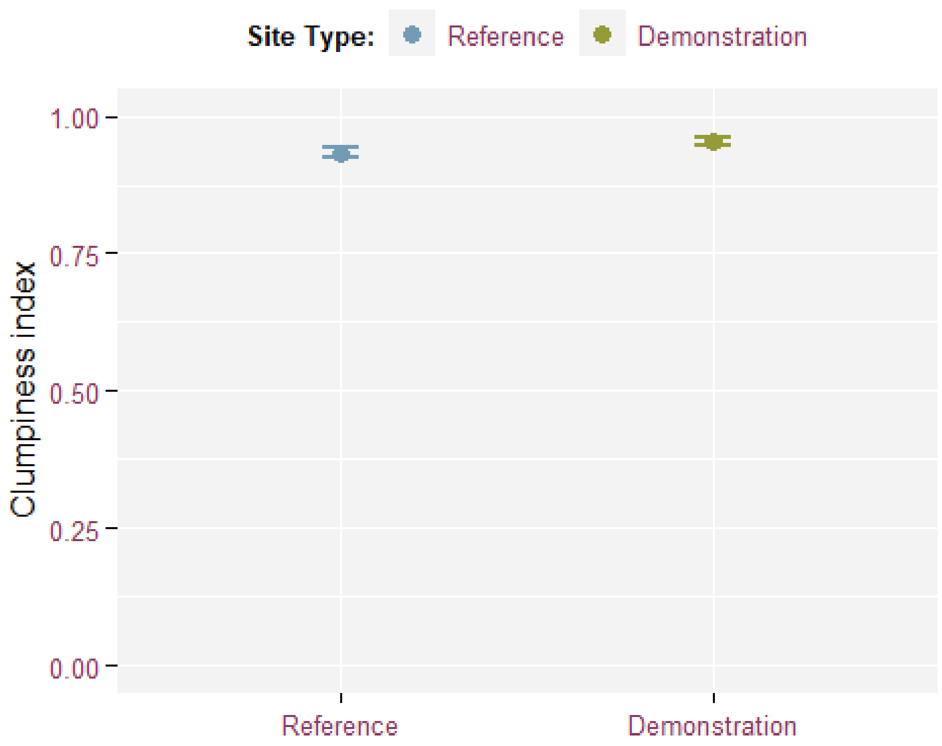


Figure A2-14: The difference in the clumpiness index of brood-rearing habitat of our project sites in the final three years of the project (2020 - 2022).

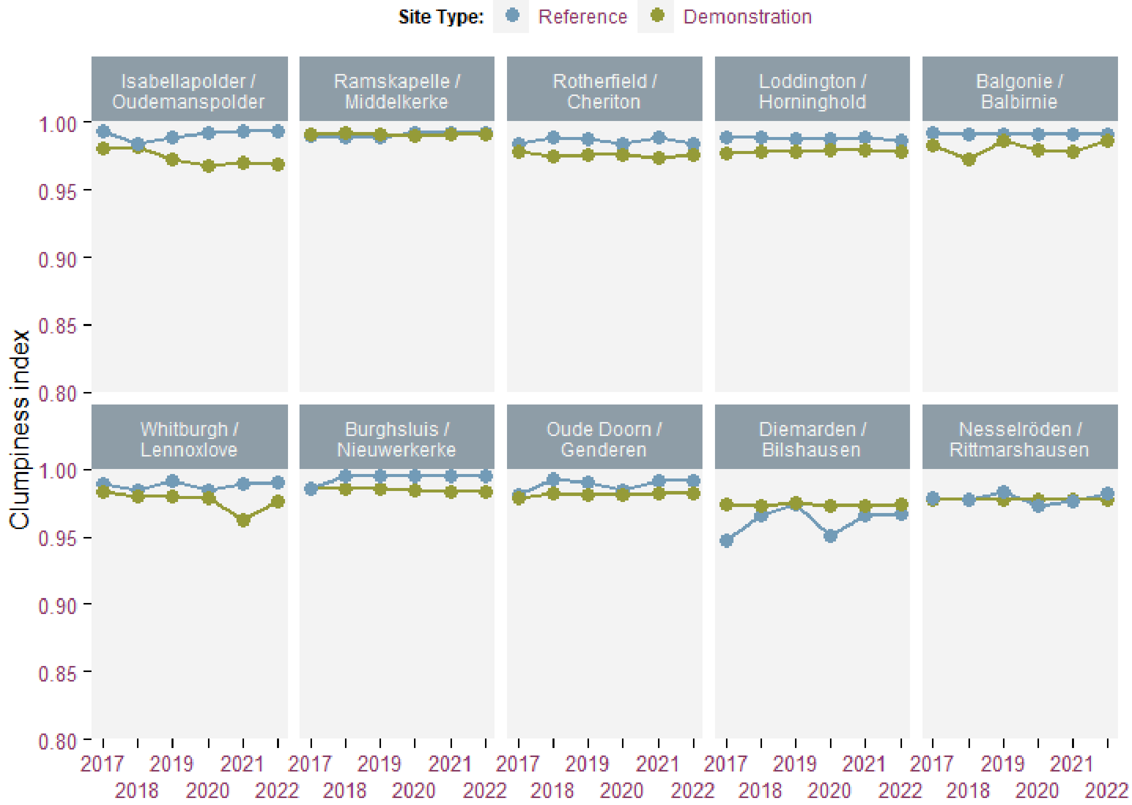


Figure A2-15: Changes over time in the clumpiness index of overwinter cover habitat at our project sites.

We were also unable to detect a significant interaction between time and site type in the clumpiness of overwinter cover habitat ($F_{(1, 98)}$ = 6.74, *p* = 0.011, Figure A2-15). Site type, also, was not found to have a significant effect on the clumpiness of habitats ($F_{(1, 9)}$ = 6.06, *p* = 0.036). We did not find a significant effect of time ($F_{(1, 98)}$ = 0.00, *p* = 0.959).

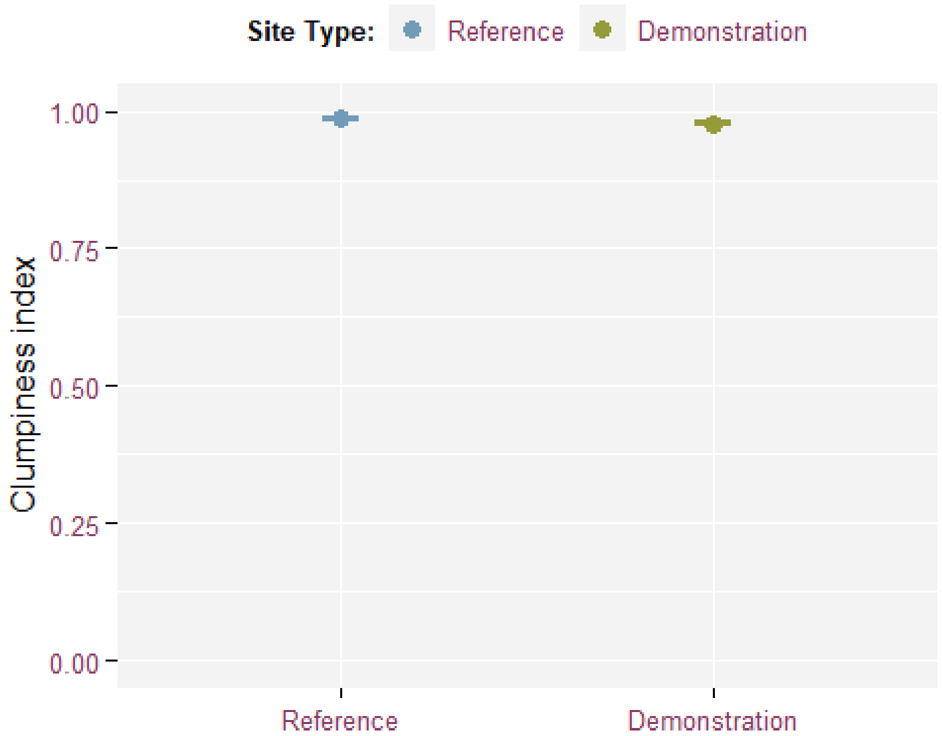


Figure A2-16: The difference in the clumpiness index of overwinter cover habitat of our project sites in the final three years of the project (2020 - 2022).

Normalized landscape shape index

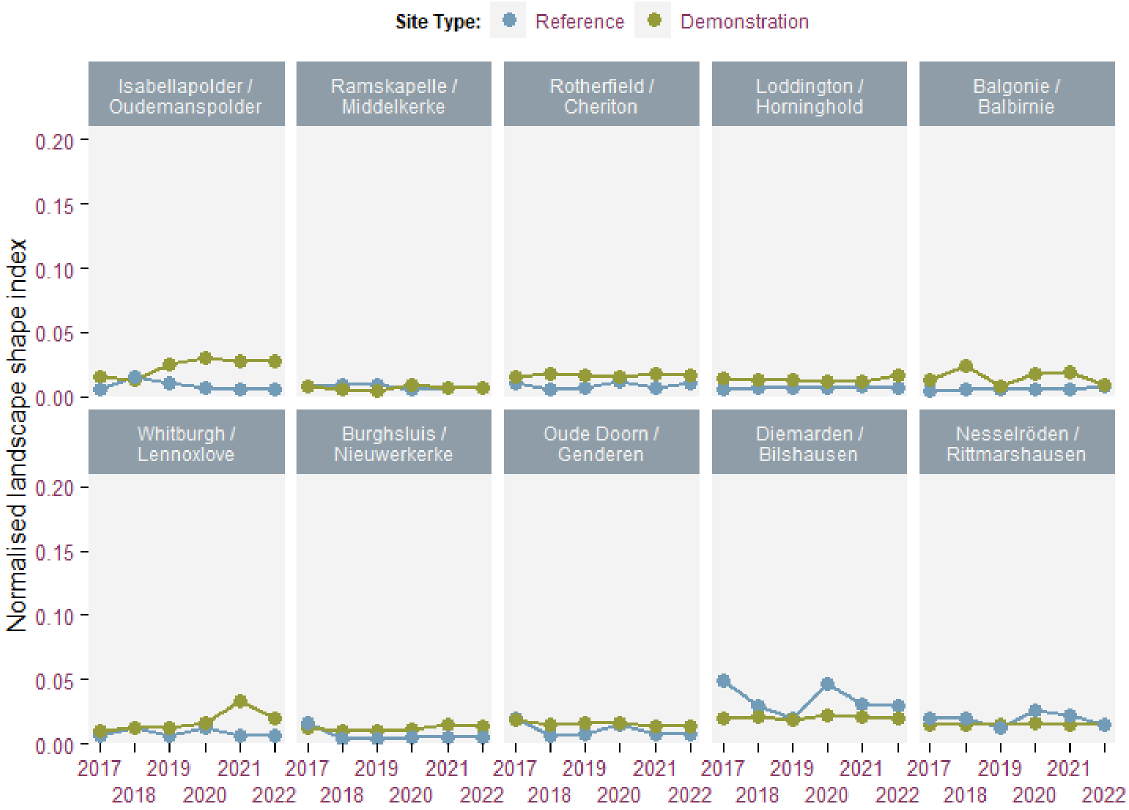


Figure A2-17: Changes over time in the normalized landscape shape index values of overwinter cover habitat at our project sites.

Lastly, we were also unable to detect a significant interaction between site type and time on the normalised landscape shape index of overwinter cover habitat at our project sites ($F_{(1, 98)}$ = 5.59, p = 0.020, Figure A2-17), nor did we detect a significant difference between these values at our demonstration and reference sites ($F_{(1, 9)}$ = 6.70, p = 0.029). These values did not change significantly throughout the duration of the project ($F_{(1, 98)}$ = 0.03, p = 0.854).

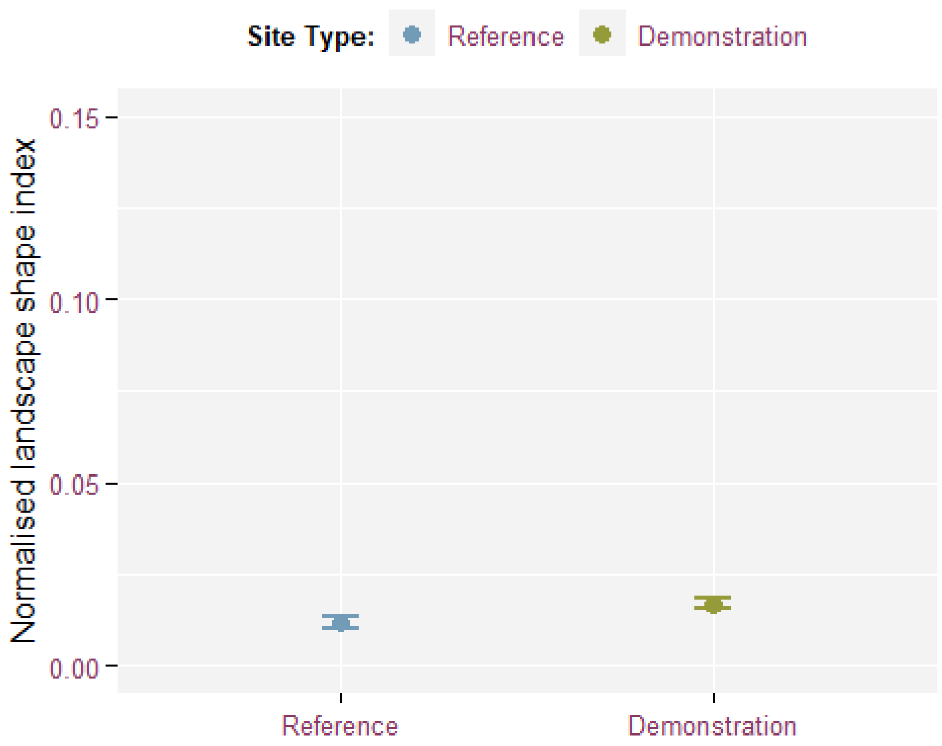


Figure A2-18: The difference in the normalised landscape shape index of overwinter cover habitat of our project sites in the final three years of the project (2020 - 2022).

Euclidean nearest neighbour distance

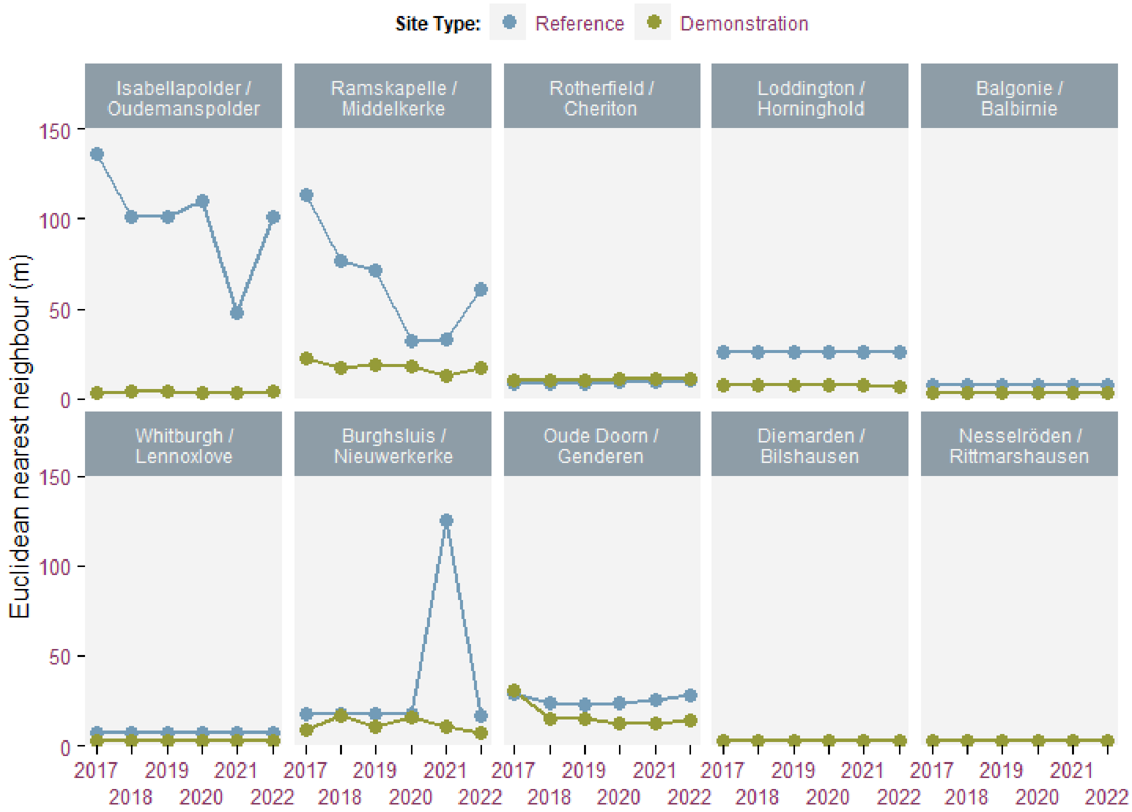


Figure A2-19: Changes over time in the average Euclidean nearest neighbour distances between nesting habitat at our project sites.

We did not detect a significant interaction between site type and time when investigating the average Euclidean nearest neighbour distance of nesting habitat at our project sites ($F_{(1, 98)}$ = 0.44, p = 0.508, Figure A2-19). Nor did find that the effect of site type on these values was significant ($F_{(1, 9)}$ = 7.25, p = 0.025). We did not detect a significant change in these values over the course of the project ($F_{(1, 98)}$, = 1.74, p = 0.190).

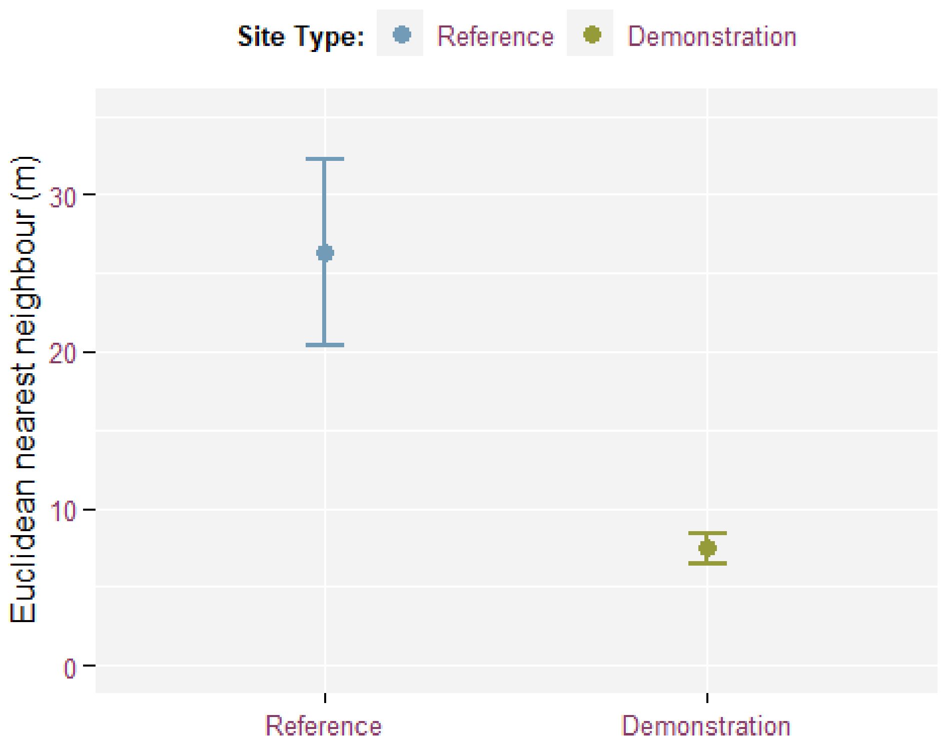


Figure A2-20: The difference in the Euclidean nearest neighbour distance of nesting habitat of our project sites in the final three years of the project (2020 - 2022). Note different y-axis to Figure A2-19.

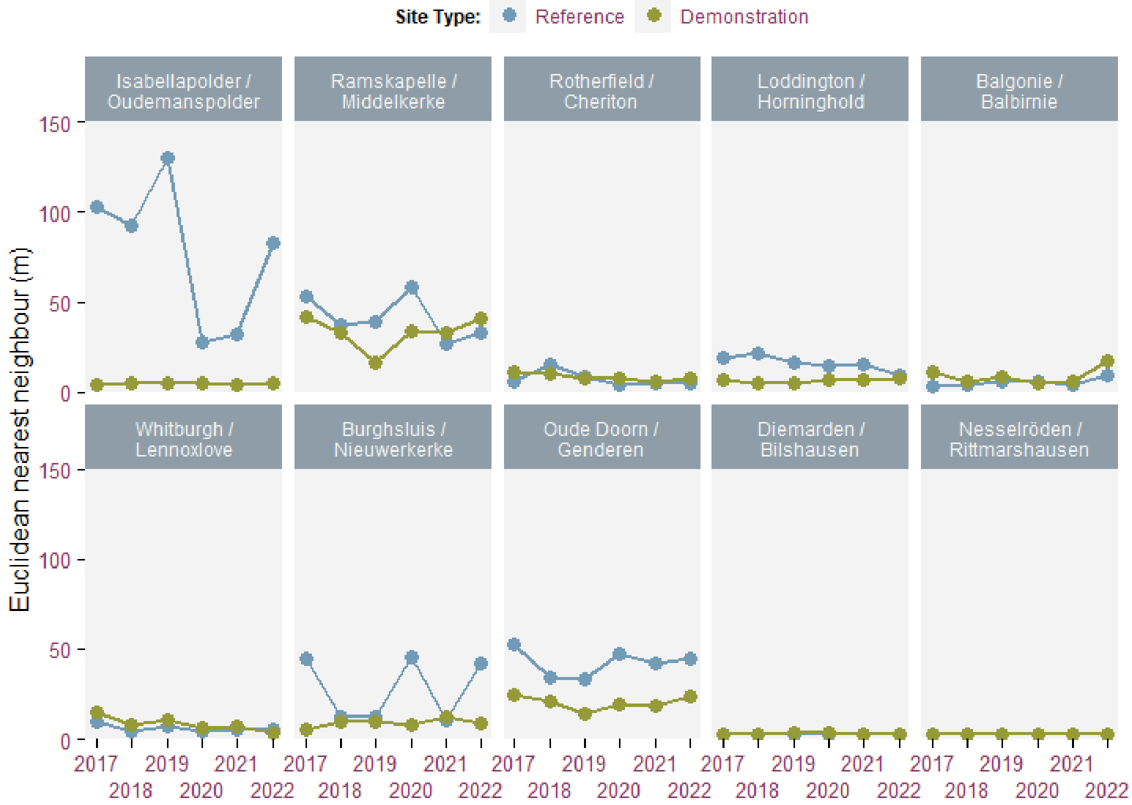


Figure A2-21: Changes over time in the average Euclidean nearest neighbour distances between overwinter cover habitat at our project sites.

We did not detect a significant interaction between site type and time when investigating the average Euclidean nearest neighbour distance of overwinter cover habitat between our demonstration and reference sites ($F_{(1, 98)} = 0.93$, $p = 0.338$, Figure A2-21). Likewise, we were also unable to detect a significant effect of site type on these values ($F_{(1, 9)} = 2.03$, $p = 0.188$), nor did we detect a significant effect of time on average distances between these habitats ($F_{(1, 98)} = 2.65$, $p = 0.107$).

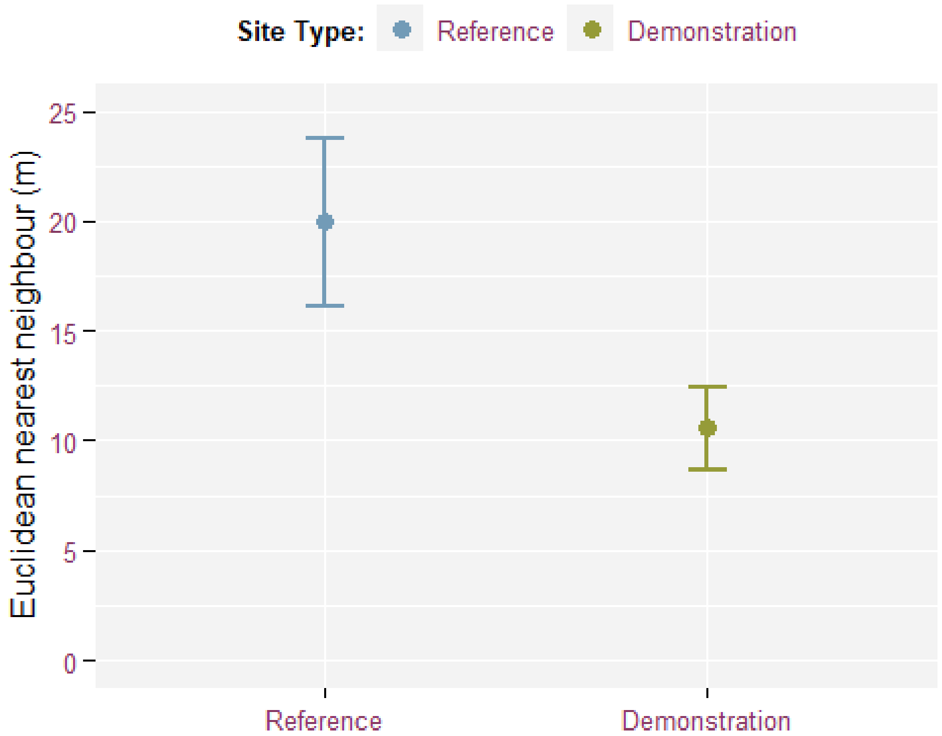


Figure A2-22: The difference in the Euclidean nearest neighbour distance of overwinter cover habitat of our project sites in the final three years of the project (2020 - 2022). Note different y-axis to Figure A2-21.

Edge density

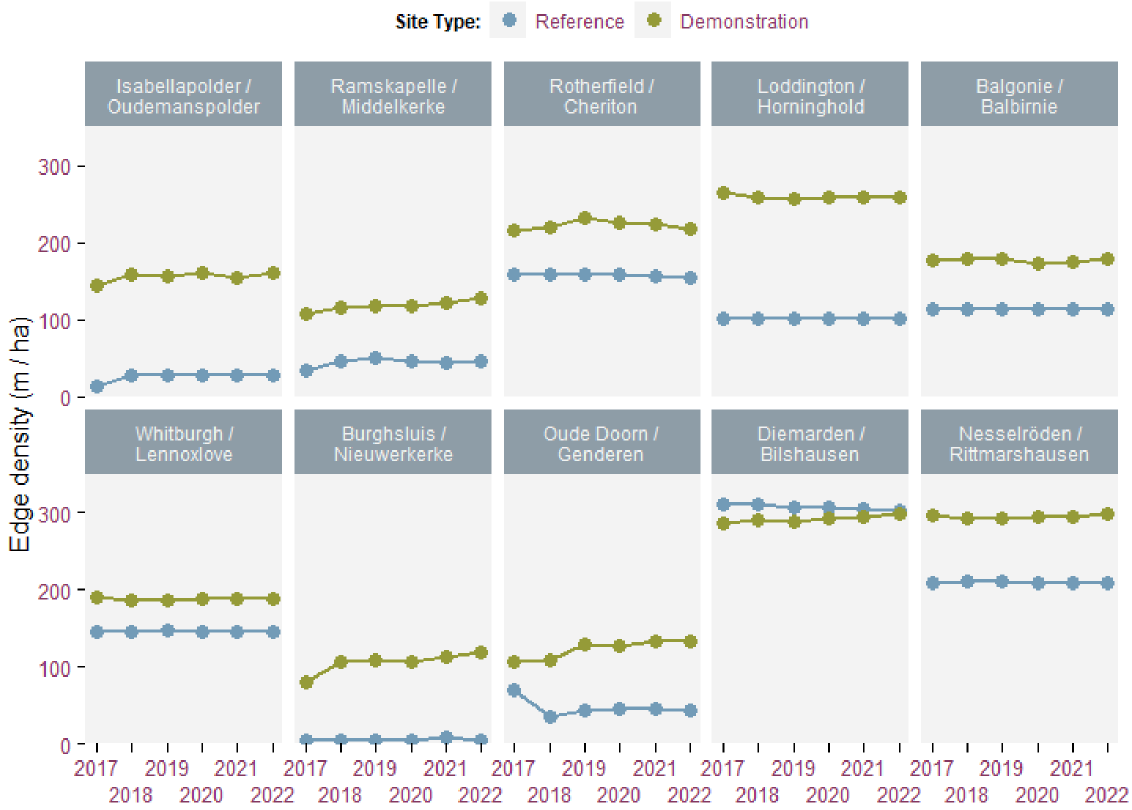


Figure A2-23: Changes over time in the edge density of nesting habitat at our project sites.

We did not detect a significant interaction between site type and time when investigating the edge density of nesting habitat at our project sites ($F_{(1, 98)}$ = 0.12, *p* = 0.735, Figure A2-23). We also did not detect a significant effect of site type on the edge density of these habitats ($F_{(1, 9)}$ = 9.96, *p* = 0.012). We did not find that time had a significant effect on these values ($F_{(1, 98)}$ = 6.71, *p* = 0.011).

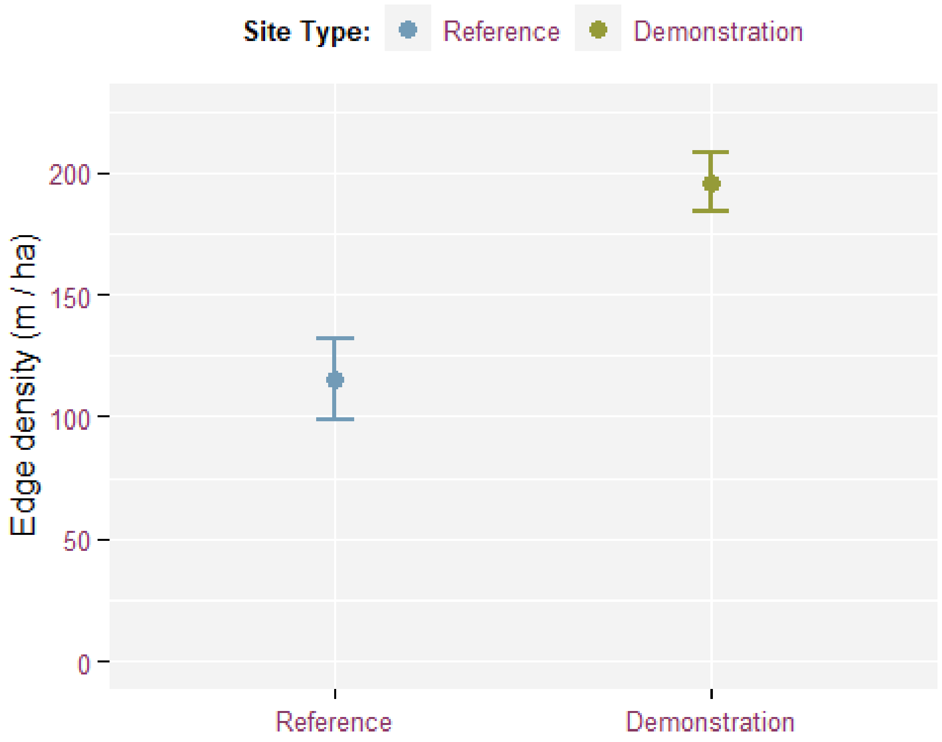


Figure A2-24: The difference in the edge density of nesting habitat of our project sites in the final three years of the project (2020 - 2022).

Mean contiguity index

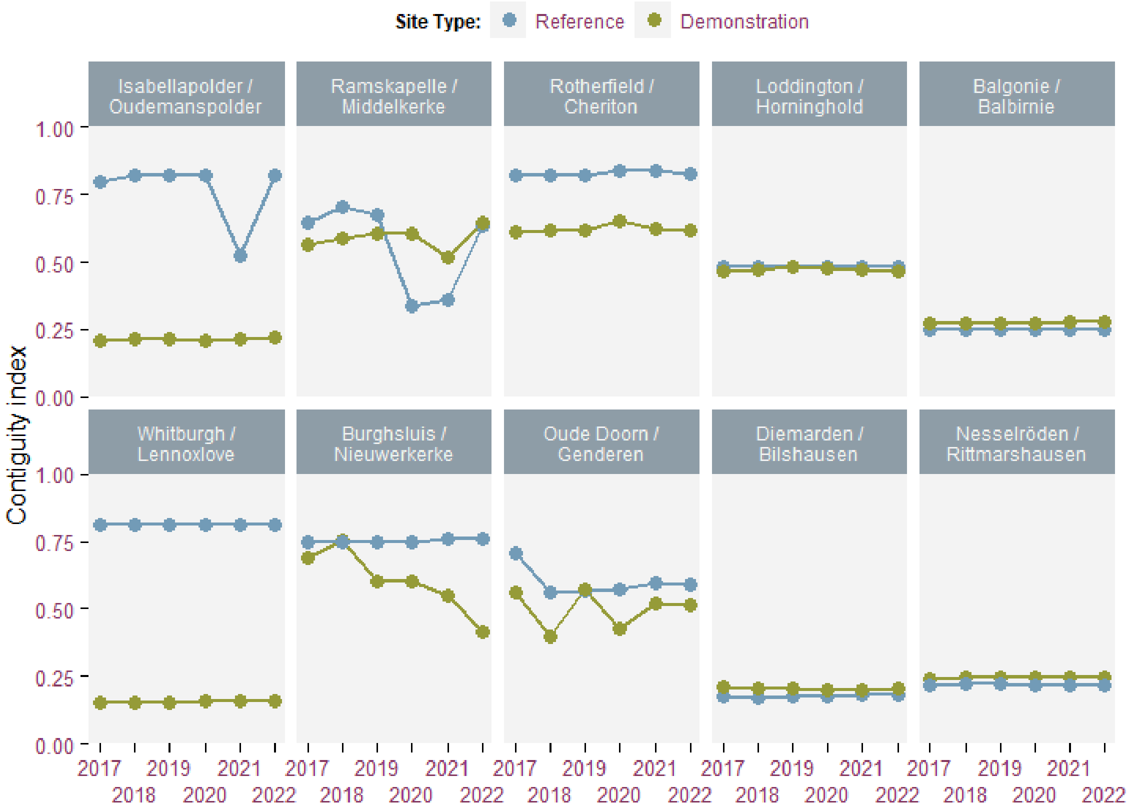


Figure A2-25: Changes over time in the contiguity index values of nesting habitat at our project sites.

We were unable to detect a significant interaction between site type and time when considering the contiguity index of nesting habitats at our project sites ($F_{(1, 98)}$ = 0.25, p = 0.621, Figure A2-25). Furthermore, we were also unable to find a significant effect of site type on the contiguity of our project sites ($F_{(1, 9)}$ = 2.65, p = 0.138). We did not detect significant changes in these values through time ($F_{(1, 98)}$ = 2.62, p = 0.109).

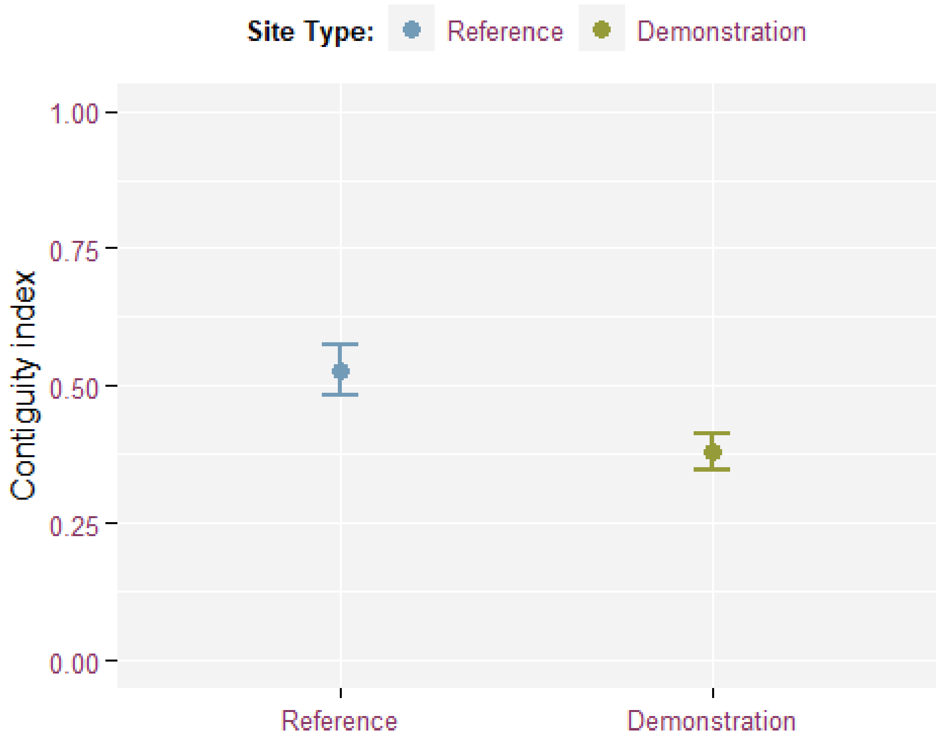


Figure A2-26: The difference in the contiguity index of nesting habitat of our project sites in the final three years of the project (2020 - 2022).

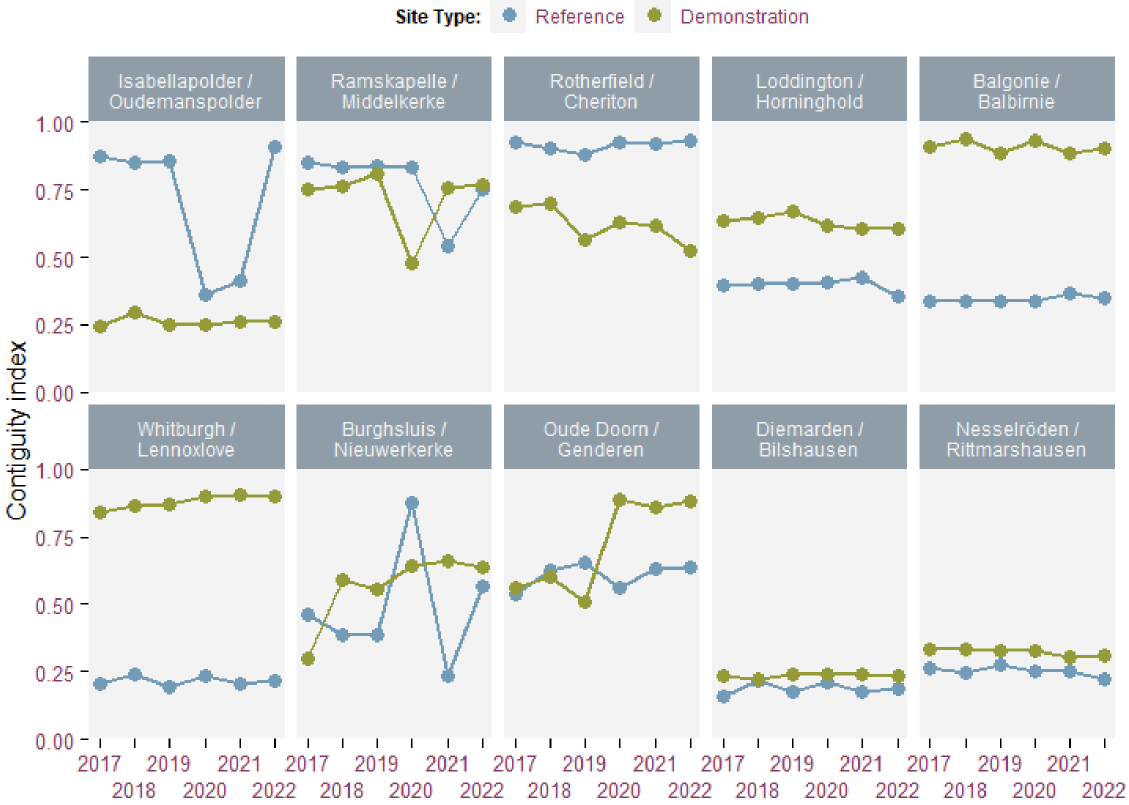


Figure A2-27: Changes over time in the contiguity index values of overwinter cover habitat at our project sites.

Lastly, we considered the contiguity of overwinter cover habitat at project sites (Figure A2-27). We were once again unable to detect a significant interaction between site type and time ($F_{(1, 98)}$ = 1.99, p = 0.161). The difference in the contiguity of habitat between our demonstration and reference sites was not found to be significant ($F_{(1, 9)}$ = 1.19, p = 0.303). Index values, also, did not change significantly through time ($F_{(1, 98)}$ = 0.04, p = 0.844).

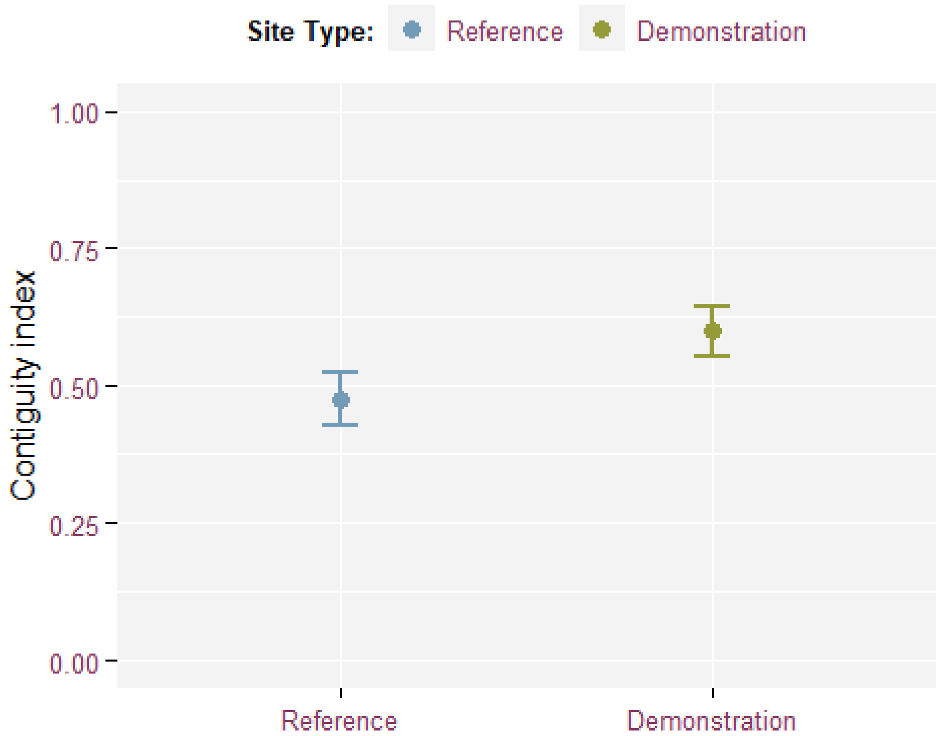


Figure A2-28: The difference in the contiguity index of overwinter cover habitat of our project sites in the final three years of the project (2020 - 2022).

Effect of no. farmers on aggregation metrics

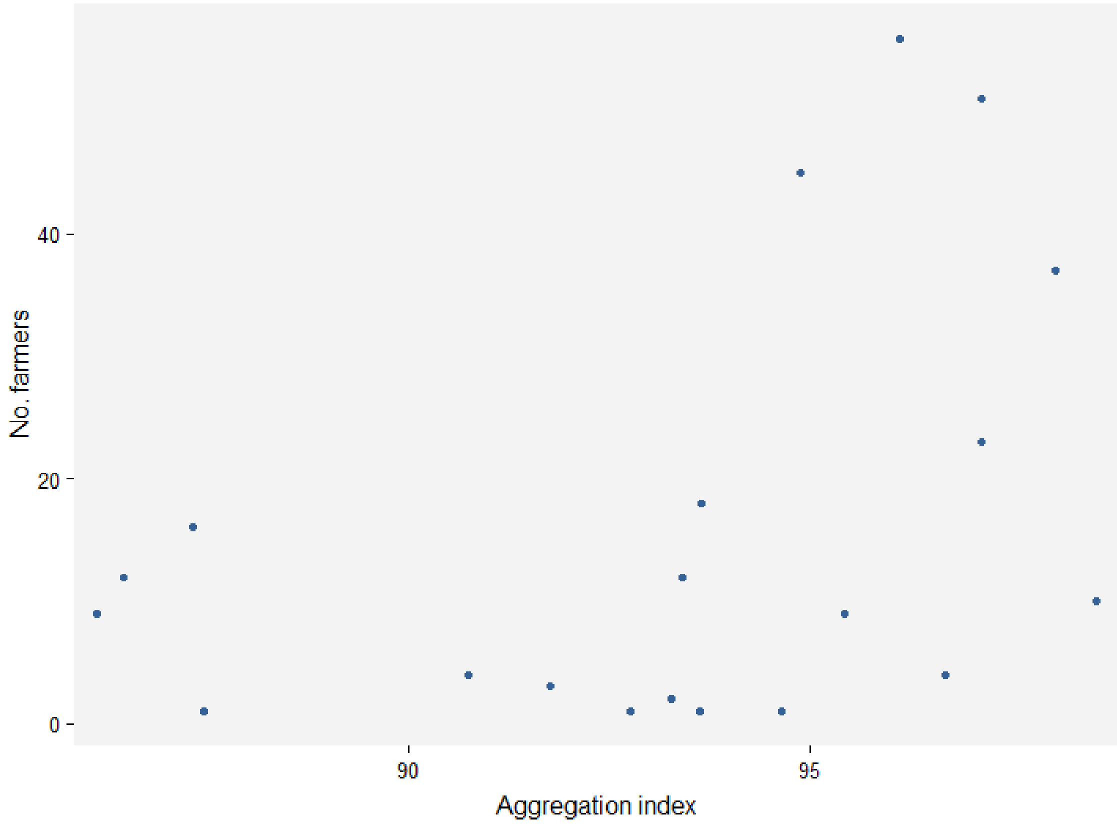


Figure A2-29: Relationship between the number of farmers and the aggregation index of nesting habitat at our demonstration sites.

Simple linear regression was used to determine if the number of farmers at our demonstration sites was related to the aggregation of nesting habitat, in this case through the aggregation index of these habitats (Figure A2-29). The overall regression was not significant (R^2 = 0.39, $F_{(1, 8)}$ = 5.18, p = 0.052).

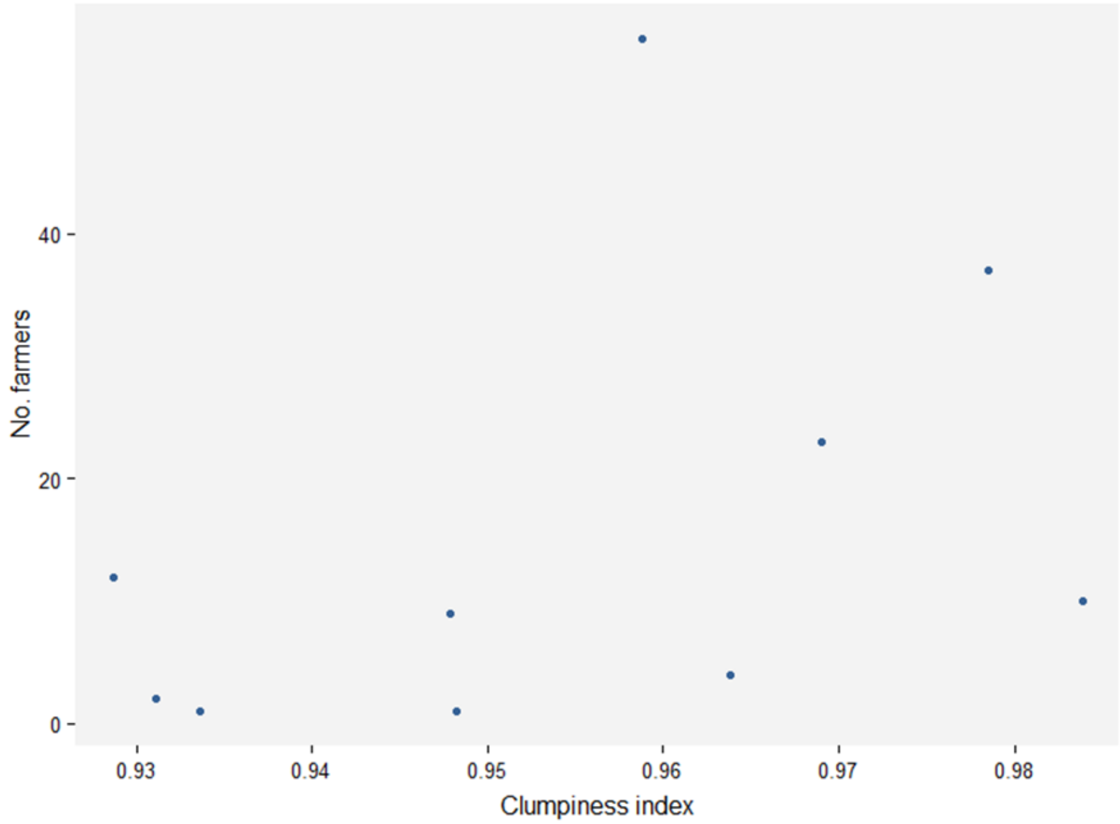


Figure A2-30: Relationship between the number of farmers and the clumpiness index of nesting habitat at our demonstration sites.

Simple linear regression was used to determine if the number of farmers at our demonstration sites predicted the aggregation of nesting habitat, in this case through the clumpiness index of these habitats (Figure A2-30). The overall regression was not significant (R^2 = 0.30, $F_{(1, 8)}$ = 3.37, p = 0.104).

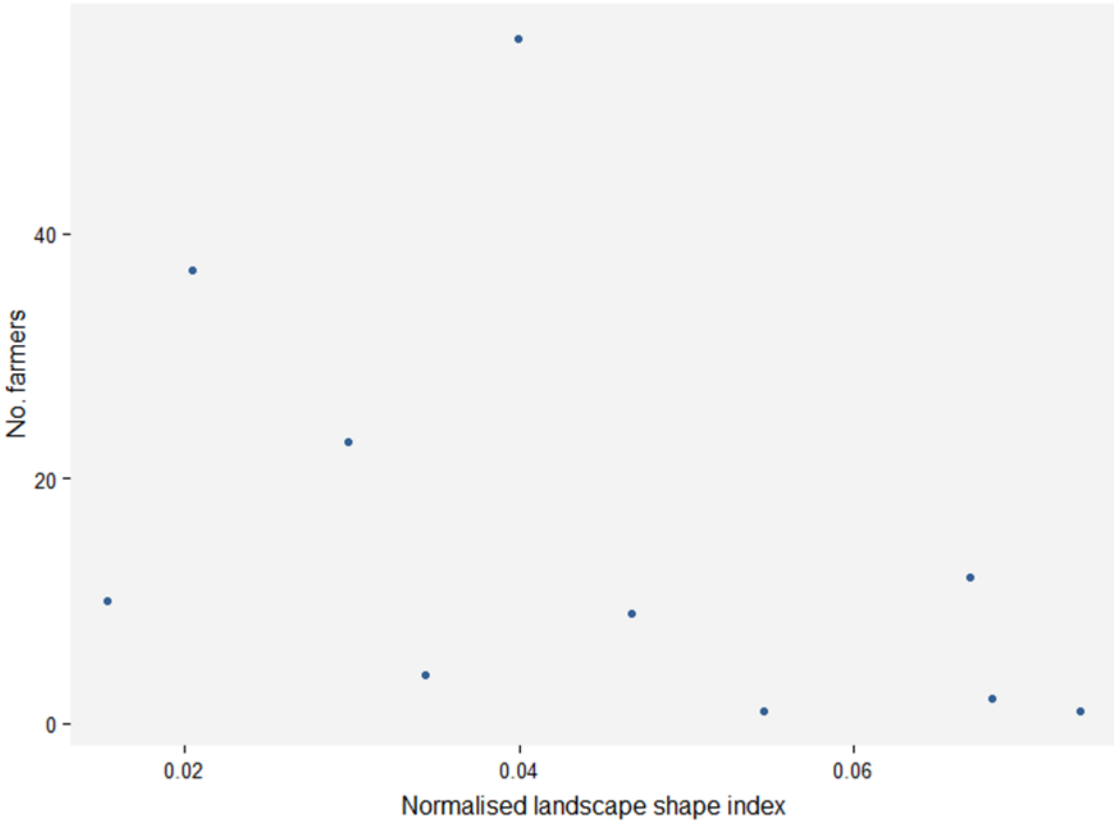


Figure A2-31: Relationship between the number of farmers and the normalised landscape shape index of nesting habitat at our demonstration sites.

Simple linear regression was used to determine if the number of farmers at our demonstration sites predicted the aggregation of nesting habitat, in this case through the normalised landscape shape index of these habitats (Figure A2-31). The overall regression was not significant (R^2 = 0.32, $F_{(1, 8)}$ = 3.81, p = 0.087).

Patch-level metrics

Field size

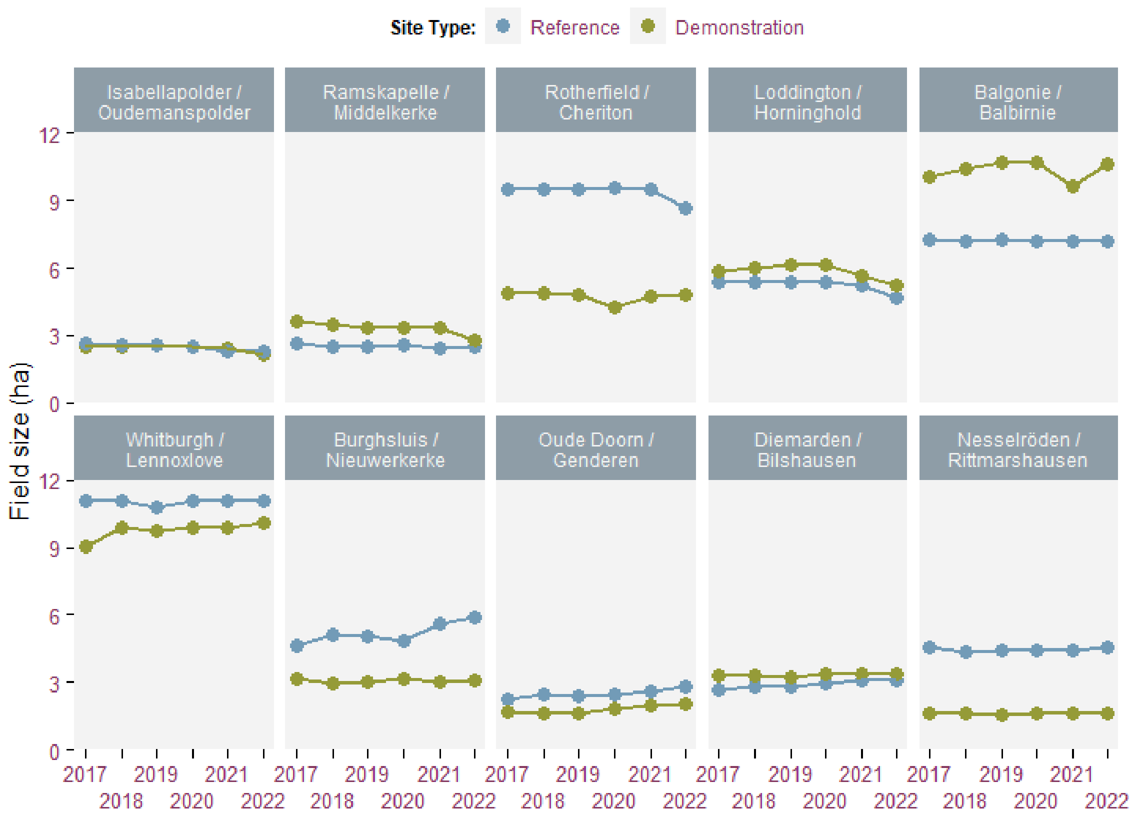


Figure A2-32: Differences in average crop field sizes over time.

We did not find a significant interaction between site type and time on the average size of crop fields at our project sites ($F_{(1, 98)}$ = 0.91, p = 0.343, Figure A2-32), nor did we find that site type had a significant effect on field sizes ($F_{(1, 9)}$ = 1.69, p = 0.226). Field size was not found to have changed significantly throughout the duration of the project ($F_{(1, 98)}$= 0.07, p = 0.799).

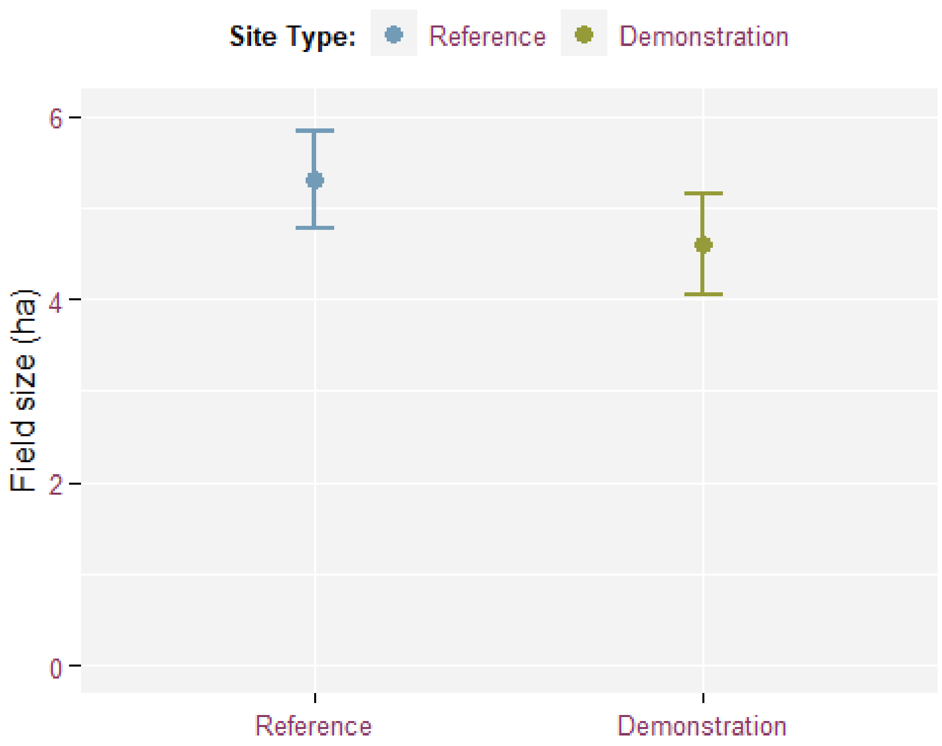


Figure A2-33: The difference in the field sizes of our project sites in the final three years of the project (2020 - 2022).

Beneficial habitat size

Mean polygon area

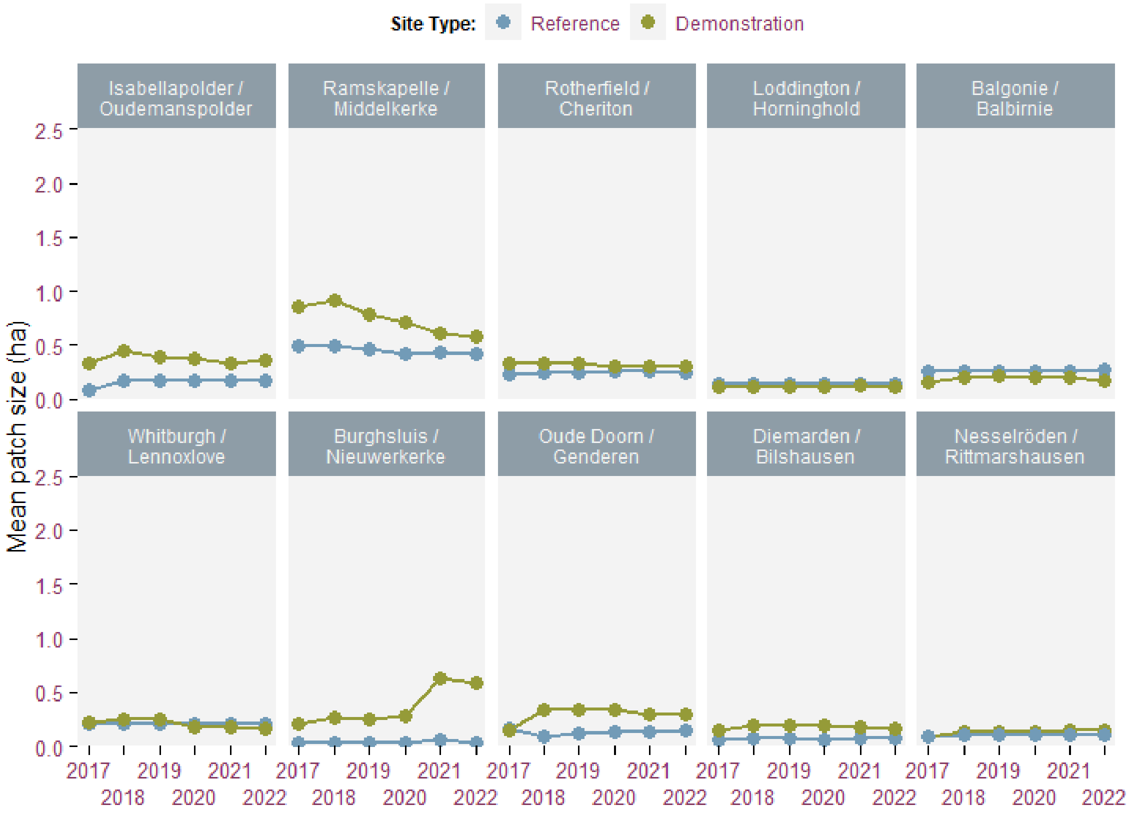


Figure A2-34: Changes over time in the mean polygon size (ha) of nesting habitat at our project sites.

We did not detect a significant interaction between time and site type when considering the average polygon size of nesting habitat at our project sites ($F_{(1, 98)} = 0.01$, $p = 0.927$, Figure A2-34), nor was site type found to have a significant effect on polygon size ($F_{(1, 9)} = 4.70$, $p = 0.058$). The average polygon size of nesting habitats was not found to have changed significantly through time ($F_{(1, 98)} = 4.95$, $p = 0.028$).

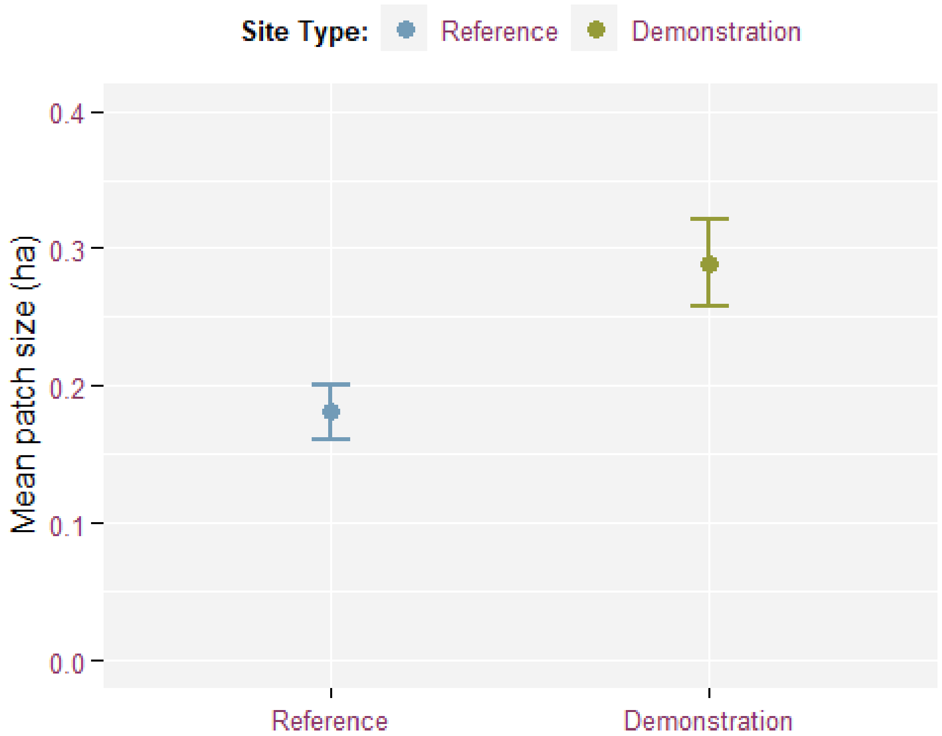


Figure A2-35: The difference in the average polygon size of nesting habitat of our project sites in the final three years of the project (2020 - 2022).). Note different y-axis to Figure A2-34.

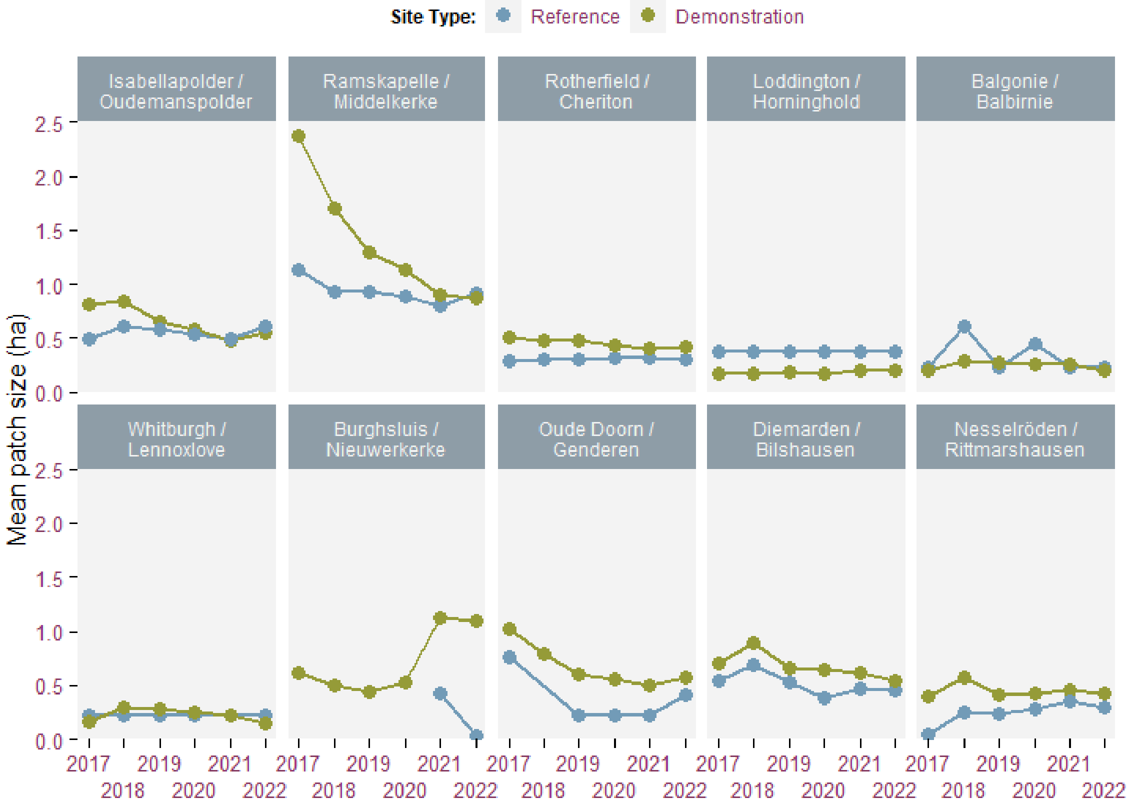


Figure A2-36: Changes over time in the mean polygon size (ha) of brood-rearing habitat at our project sites.

As with the size of nesting habitat polygons, we were also unable to detect a significant interaction between site type and time on the average area of brood-rearing habitat polygons ($F_{(1, 93.4)}$ = 0.73, p = 0.395, Figure A2-36). Site type was similarly not found to have a significant effect ($F_{(1, 8.7)}$ = 2.81, p = 0.130). Lastly, we were also unable to detect a significant effect of time on these values ($F_{(1, 93.3)}$ = 2.20, p = 0.141).

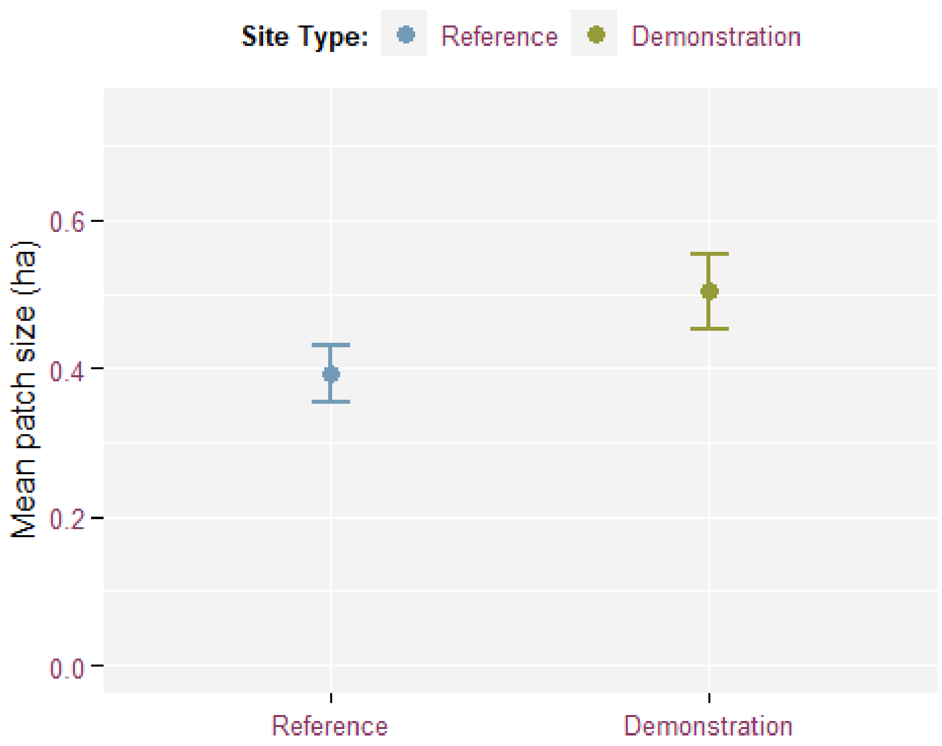


Figure A2-37: The difference in the average polygon size of brood-rearing habitat of our project sites in the final three years of the project (2020 - 2022). Note different y-axis to Figure A2-36.

Mean patch area

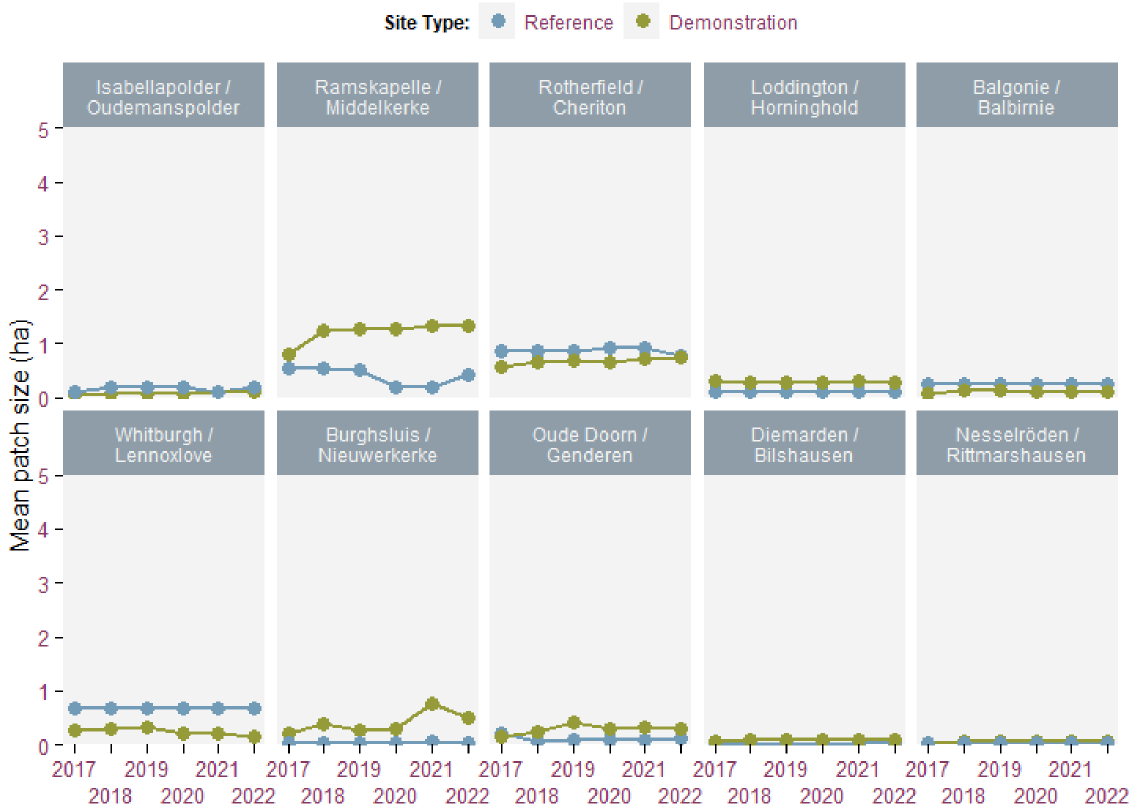


Figure A2-38: Changes over time in the mean patch size (ha) of nesting habitat at our project sites.

When analysing the average patch size of beneficial nesting habitat at our project sites we were unable to detect a significant interaction between site type and year ($F_{(1, 98)}$ = 4.45, p = 0.037, Figure A2-38), nor did we detect that site type had a significant effect on patch size ($F_{(1, 9)}$ = 1.94, p = 0.198). We were also unable to detect a significant change in the size of nesting habitat patches over time ($F_{(1, 98)}$ = 5.77, p = 0.018).

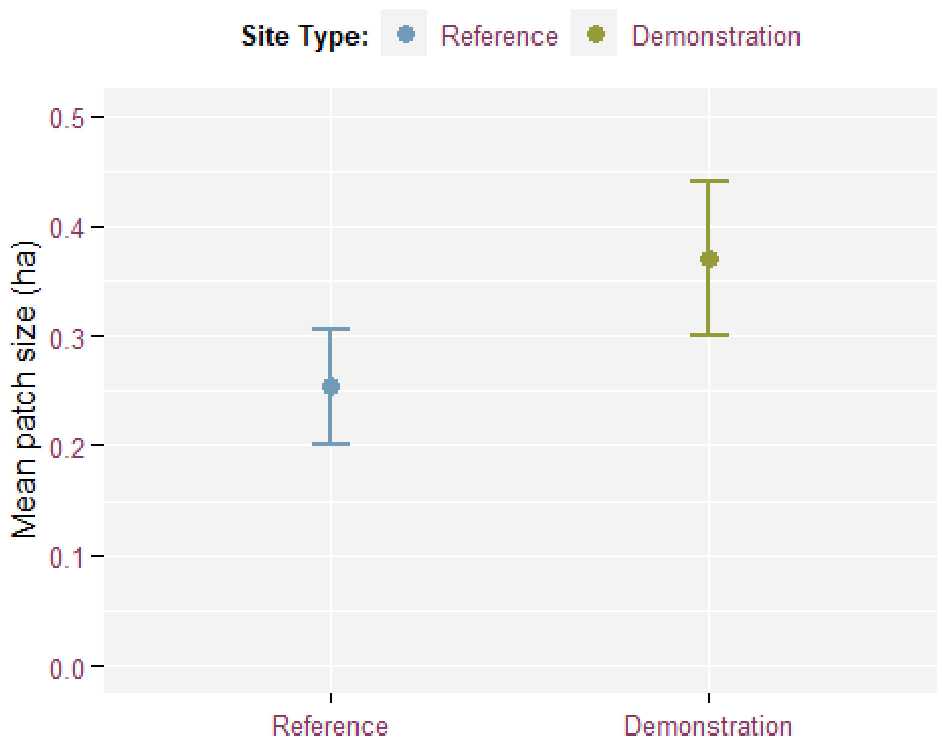


Figure A2-39: The difference in the mean patch size of nesting habitat of our project sites in the final three years of the project (2020 - 2022). Note different y-axis to Figure A2-38.

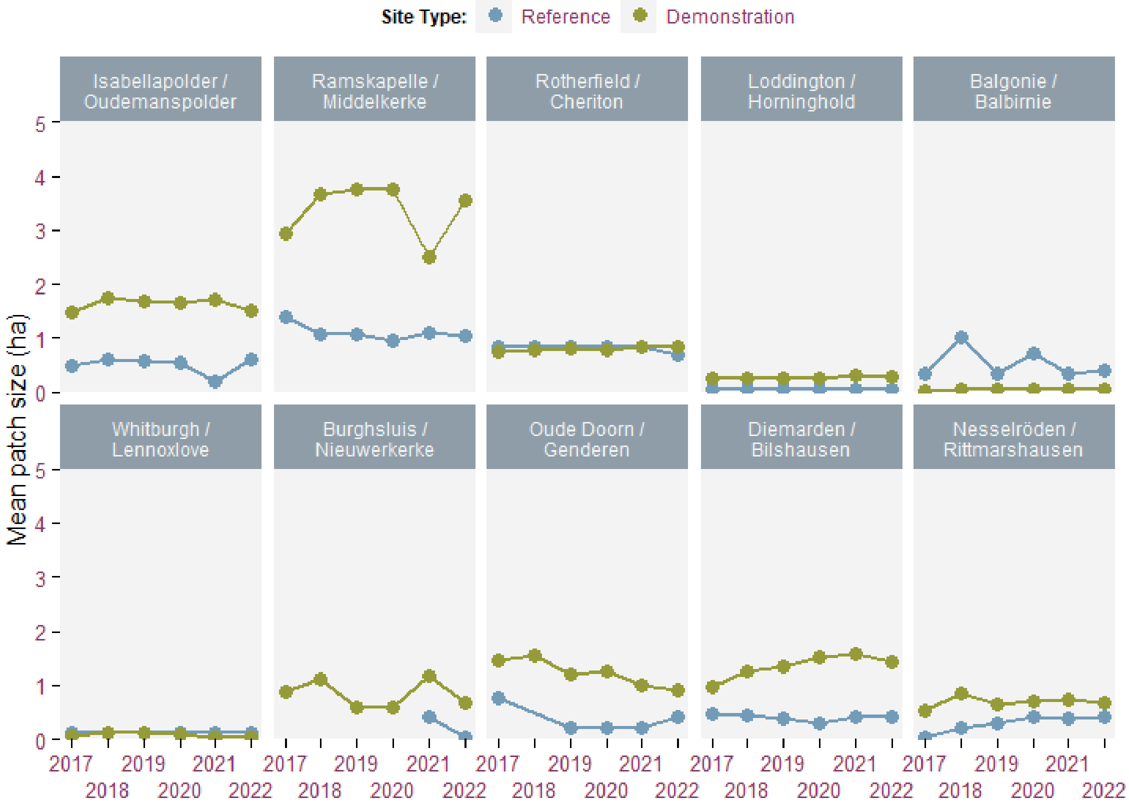


Figure A2-40: Changes over time in the mean patch size (ha) of brood-rearing habitat at our project sites.

Results were similar for the average size of brood-rearing patches - where we were also unable to detect a significant interaction between site type and time across our project sites ($F_{(1, 98)}$ = 4.14, p = 0.045, Figure A2-40). The average size of these patches was not found to differ significantly between demonstration and reference sites ($F_{(1, 9)}$ = 3.33, p = 0.101). Lastly, we did not detect a significant effect of time on the size of these patches ($F_{(1, 98)}$ = 2.56, p = 0.113).

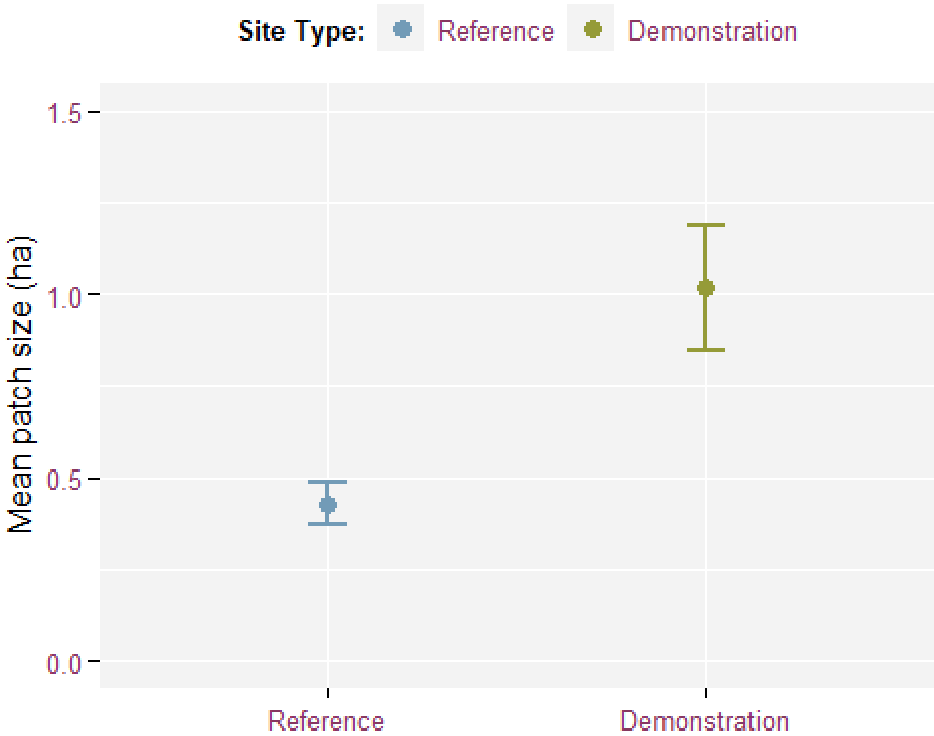


Figure A2-41: The difference in the average patch size of brood-rearing habitat of our project sites in the final three years of the project (2020 - 2022). Note different y-axis to Figure A2-40.

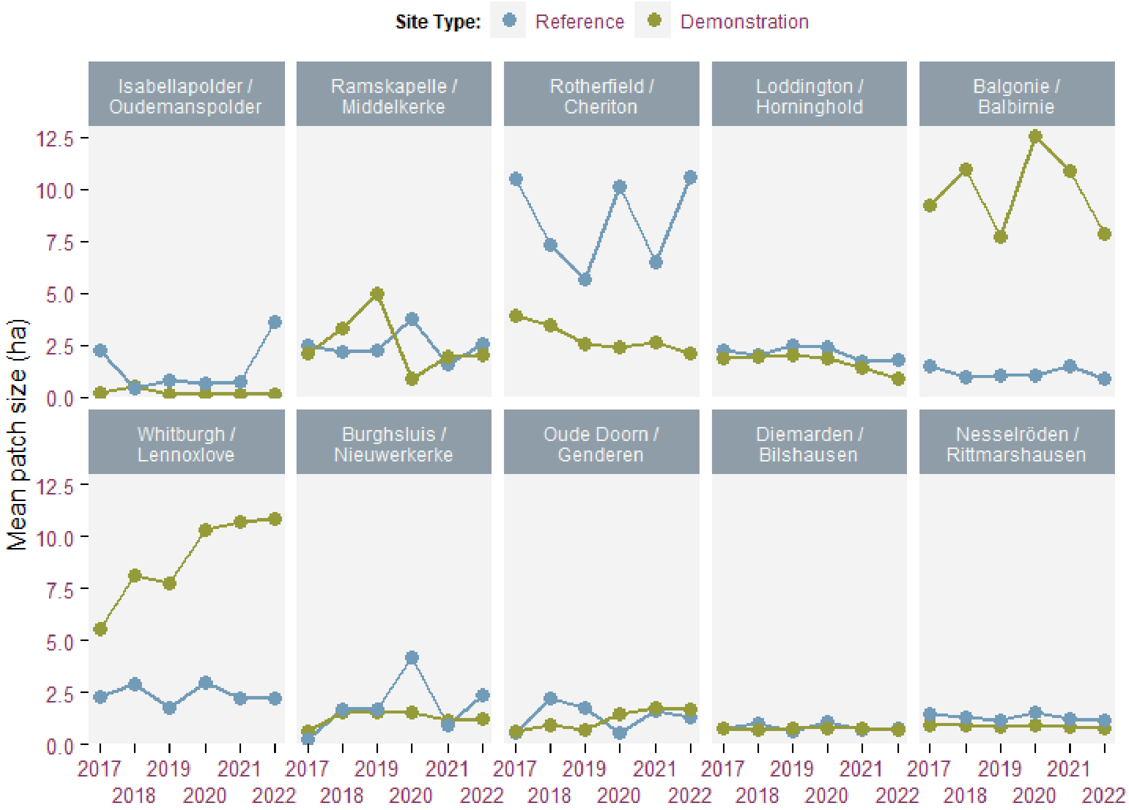


Figure A2-42: Changes over time in the mean patch size in hectares of overwinter cover habitat at our project sites.

Concerning the average size of overwinter cover habitat patches, we were also unable to find a significant interaction between site type and year ($F_{(1, 98)}$ = 0.94, p = 0.335, Figure A2-42). Site type, also, was not found to have a significant effect on these values ($F_{(1, 9)}$ = 0.01, p = 0.907). Patch size, also, was not found to have changed significantly through time ($F_{(1, 98)}$ = 0.18, p = 0.671).

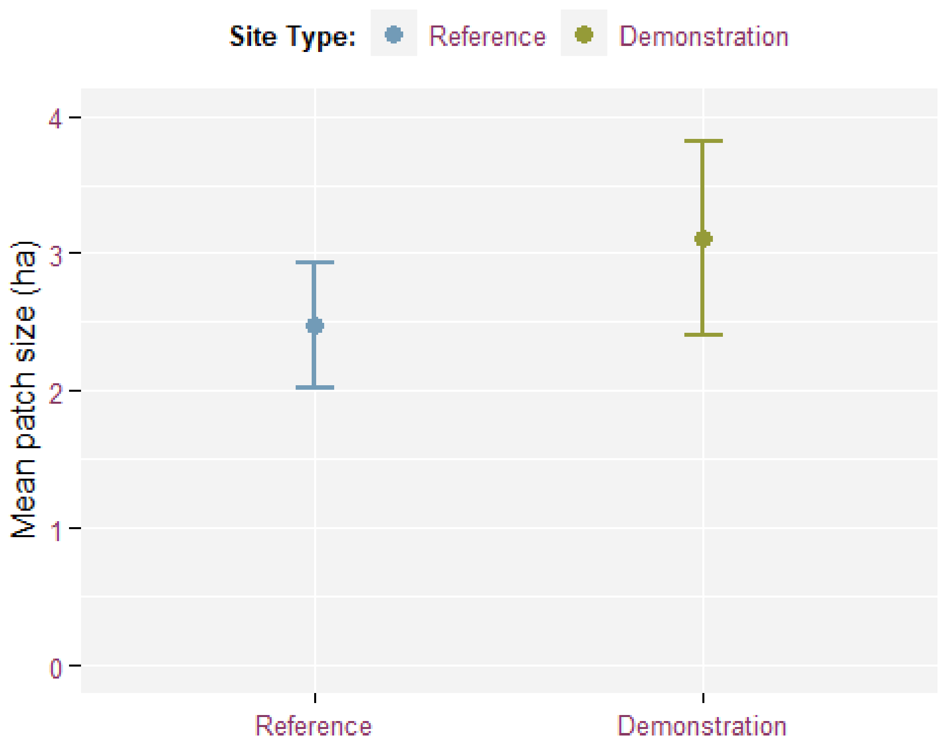


Figure A2-43: The difference in the average patch size of overwinter cover habitat of our project sites in the final three years of the project (2020 - 2022). Note different y-axis to Figure A2-42.

Mean shape index

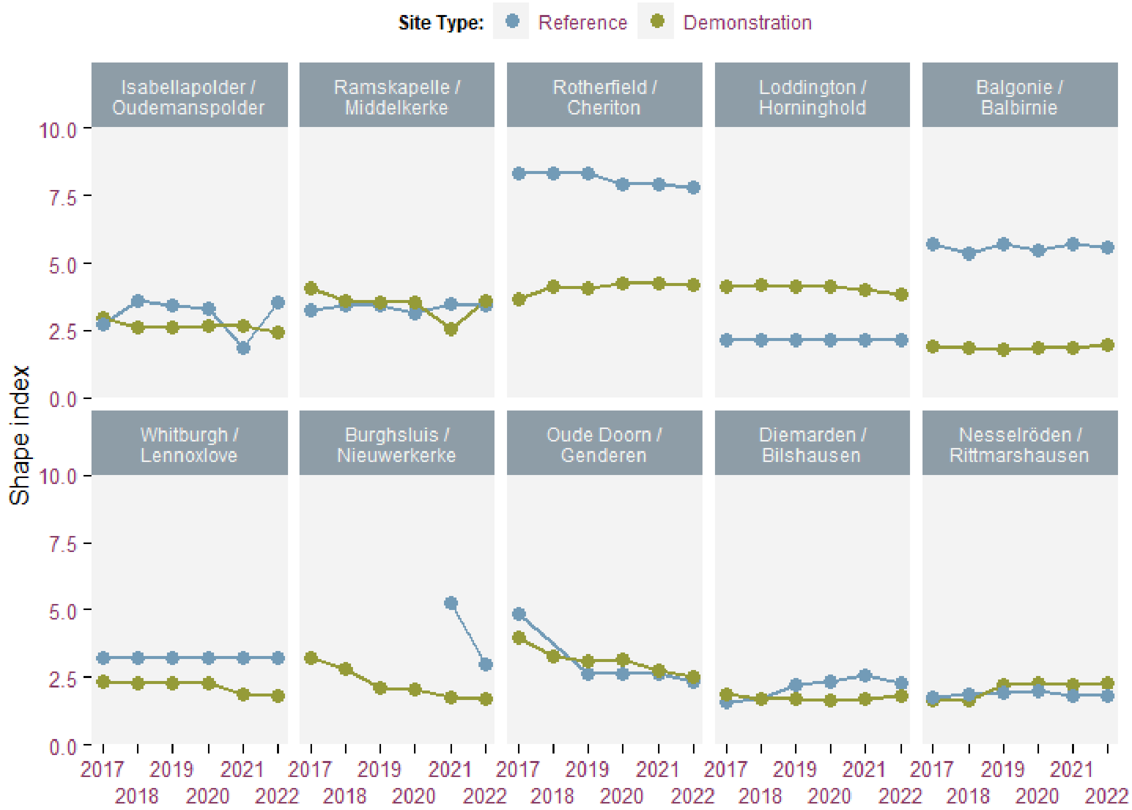


Figure A2-44: Changes over time in the mean shape index values of brood-rearing habitat at our project sites.

We were unable to detect a significant interaction between time and site type on the mean shape index of brood-rearing habitat patches at our project sites ($F_{(1, 98)} = 3.04$, $p = 0.085$, Figure A2-44). Likewise, we were unable to detect a significant effect of site type on the mean shape index of these habitats ($F_{(1, 9)} = 0.02$, $p = 0.878$). Lastly, we were unable to detect a significant change in these values over time ($F_{(1, 98)} = 0.82$, $p = 0.368$).

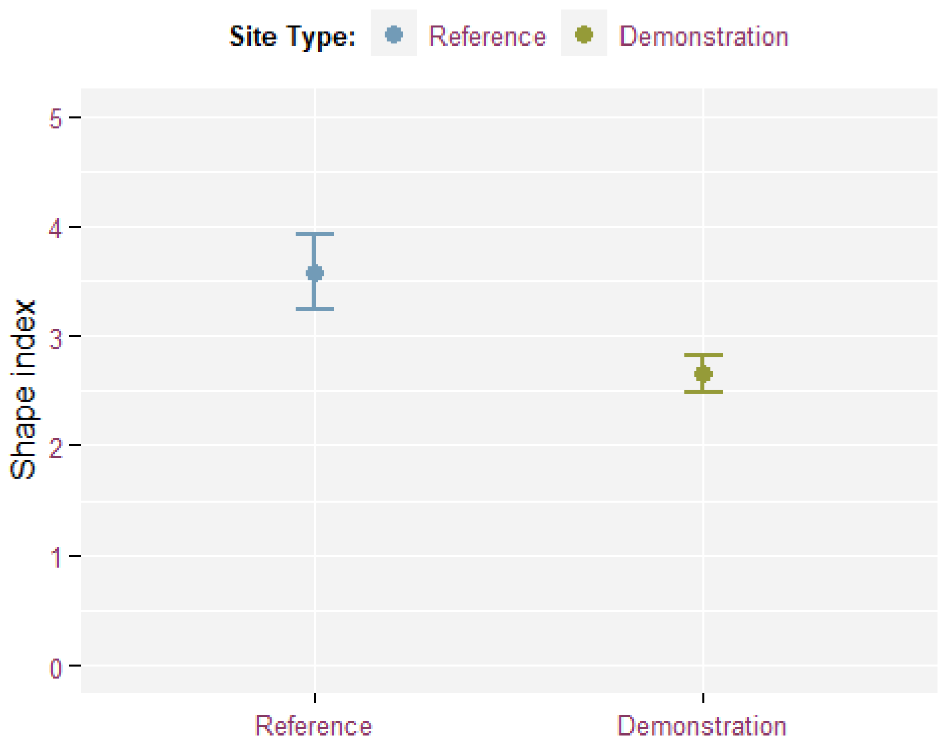


Figure A2-45: The difference in the average shape index of brood-rearing habitat of our project sites in the final three years of the project (2020 - 2022). Note different y-axis to Figure A2-44.

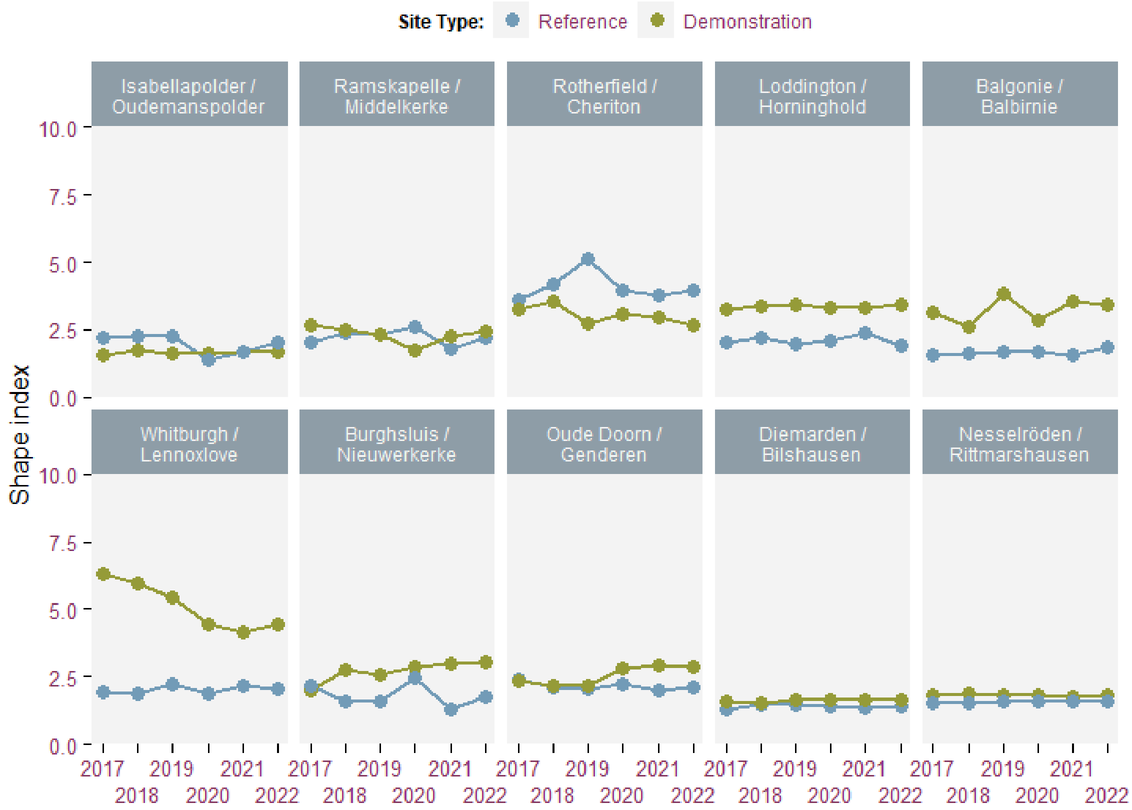


Figure A2-46: Changes over time in the mean shape index values of overwinter cover habitat at our project sites.

Lastly, we also were unable to detect a significant interaction between site type and time on the mean shape index of overwinter cover habitat patches at project sites ($F_{(1, 98)} = 0.51$, p = 0.477, Figure A2-46). We did not detect significantly different values between our demonstration and reference sites ($F_{(1, 9)} = 4.47$, p = 0.064), nor were they found to have changed significantly through time ($F_{(1, 98)} = 0.17$, p = 0.684).

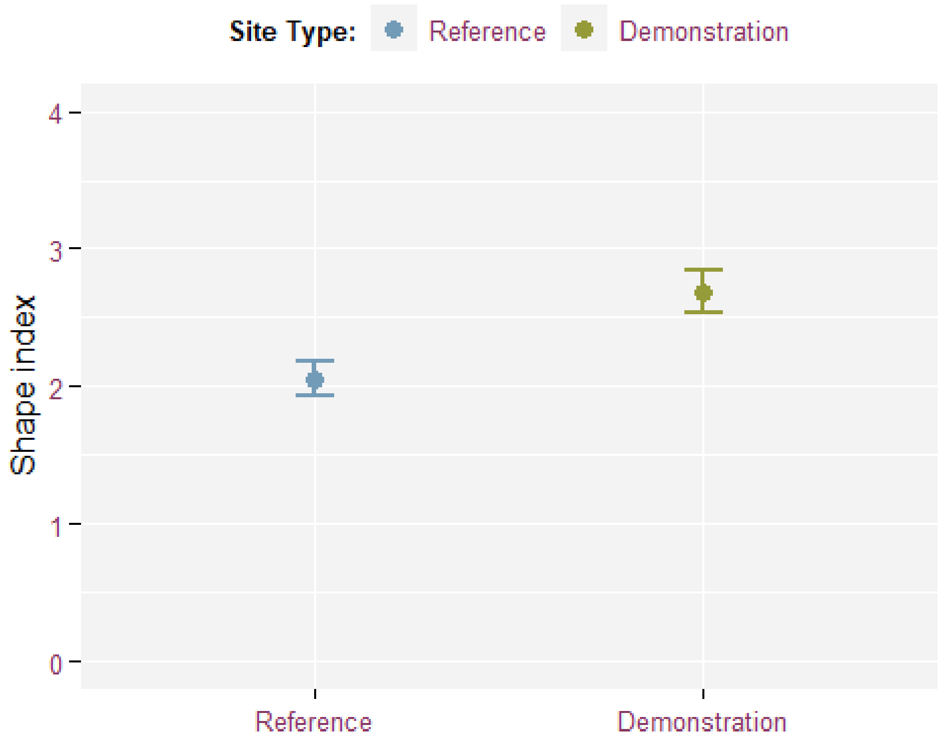


Figure A2-47: The difference in the average shape index of overwinter cover habitat of our project sites in the final three years of the project (2020 - 2022). Note different y-axis to Figure A2-46.

Mean perimeter-area ratio

Figure A2-48: Changes over time in the mean perimeter-area ratio values of nesting habitat at our project sites.

We did not find that there was a significant interaction between site type and time on the mean perimeter-area ratios of nesting habitat patches at our project sites ($F_{(1, 98)}$ = 0.14, p = 0.707, Figure A2-48). Site type was not found to have a significant effect on these values ($F_{(1, 9)}$ = 5.35, p = 0.046). These ratios were not found to have changed significantly over time ($F_{(1, 98)}$ = 3.38, p = 0.069).

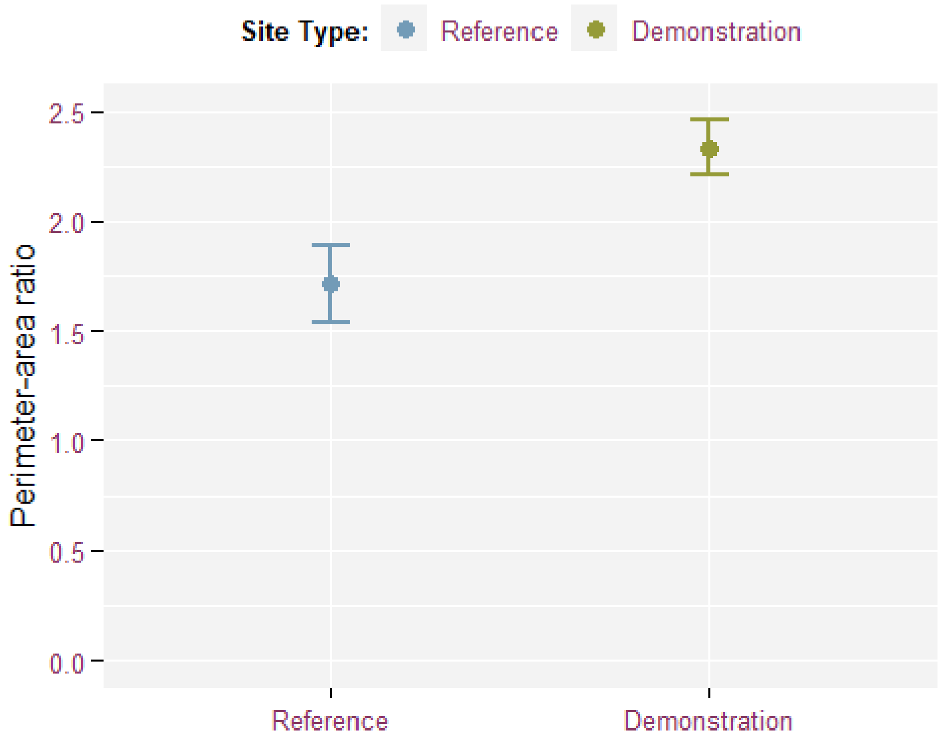


Figure A2-49: The difference in the average perimeter-to-area of nesting habitat of our project sites in the final three years of the project (2020 - 2022).

Figure A2-50: Changes over time in the mean perimeter-area ratio values of brood-rearing habitat at our project sites.

We were also unable to find a significant interaction between site type and time on the mean perimeter-area ratios of brood-rearing habitat at our project sites ($F_{(1, 98)}$ = 0.53, p = 0.467, Figure A2-50). Site type was not found to be significantly different between demonstration and reference sites ($F_{(1, 9)}$ = 0.00, p = 0.990). The mean perimeter-area ratios of brood-rearing cover were also not found to have changed significantly over the duration of the project ($F_{(1, 98)}$ = 1.64, p = 0.204).

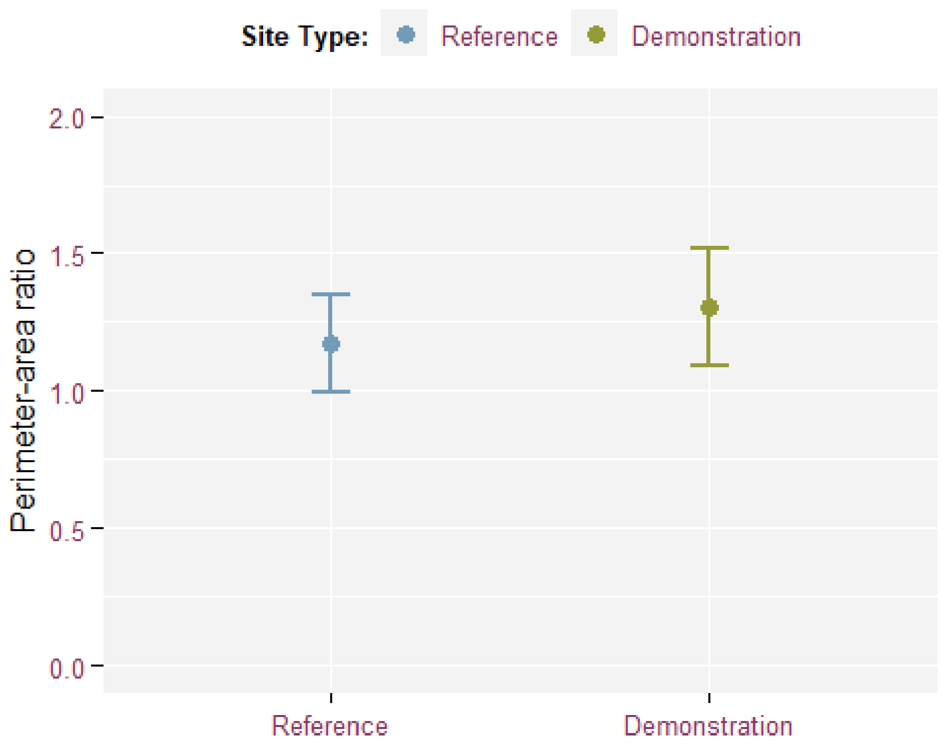


Figure A2-51: The difference in the average perimeter-to-area of brood-rearing habitat of our project sites in the final three years of the project (2020 - 2022).

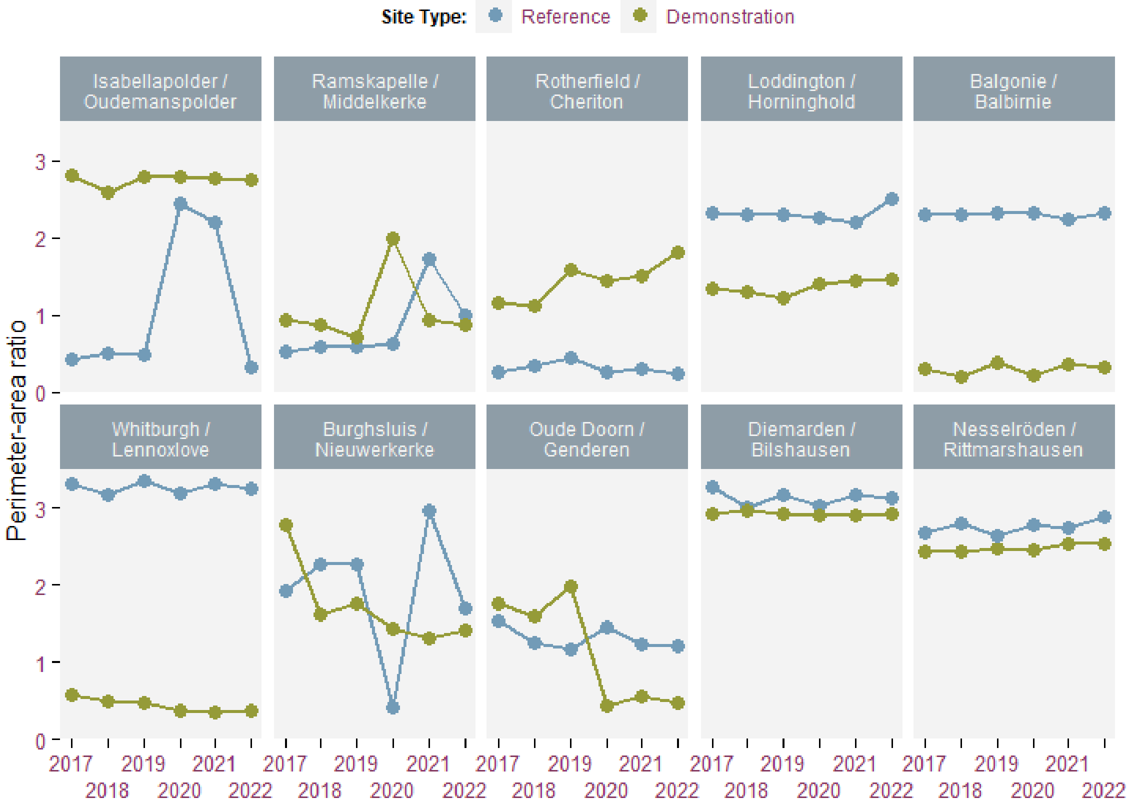


Figure A2-52: Changes over time in the mean perimeter-area ratio values of overwinter cover habitat at our project sites.

Lastly, we also were unable to find a significant interaction between site type and time on the mean perimeter-area ratios of overwinter cover habitat at our project sites ($F_{(1, 98)}$ = 2.38, p = 0.126, Figure A2-52). Values were also not found to differ significantly between our demonstration and reference sites ($F_{(1, 9)}$ = 0.35, p = 0.559). These ratios did not change significantly over the duration of the project ($F_{(1, 98)}$ = 0.13, p = 0.715).

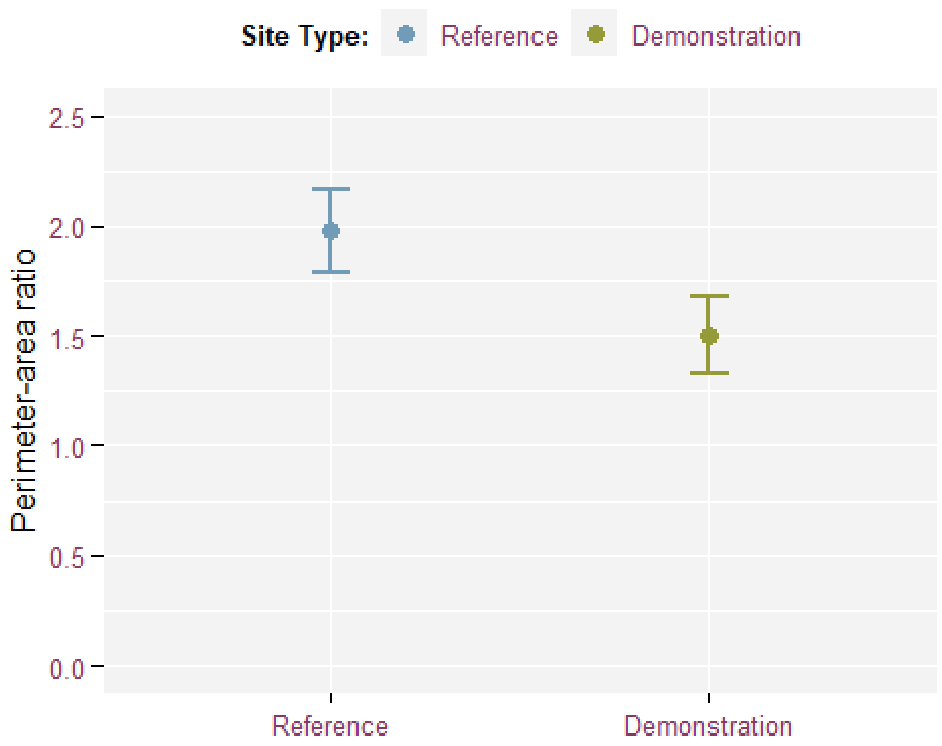


Figure A2-53: The difference in the average perimeter-to-area ratio of overwinter cover habitat of our project sites in the final three years of the project (2020 - 2022).

Mean fractal dimension index

Figure A2-54: Changes over time in the fractal dimension index values of brood-rearing habitat at our project sites.

We were also unable to detect a significant interaction between time and site type when looking at the mean fractal dimension index of brood-rearing habitat at our project sites ($F_{(1, 97)}$ = 3.64, p = 0.059, Figure A2-54). We did not find a significant effect of site type on these values ($F_{(1, 9)}$ = 0.94, p = 0.357). Values were not found to have changed significantly through time ($F_{(1, 97)}$ = 3.65, p = 0.059).

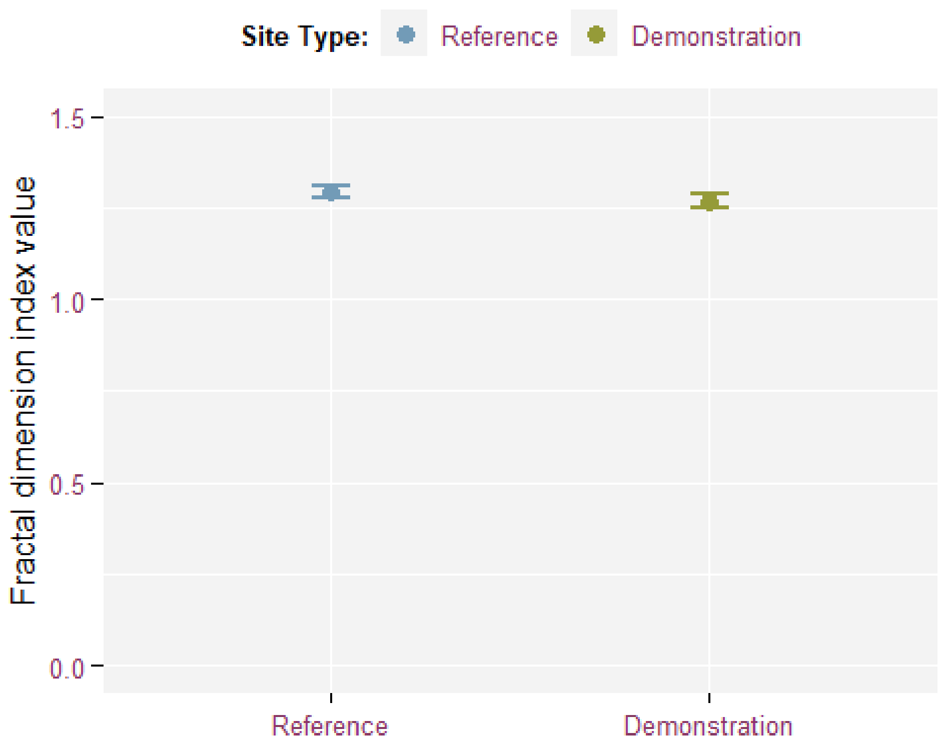


Figure A2-55: The difference in the average fractal dimension index of brood-rearing habitat of our project sites in the final three years of the project (2020 - 2022).

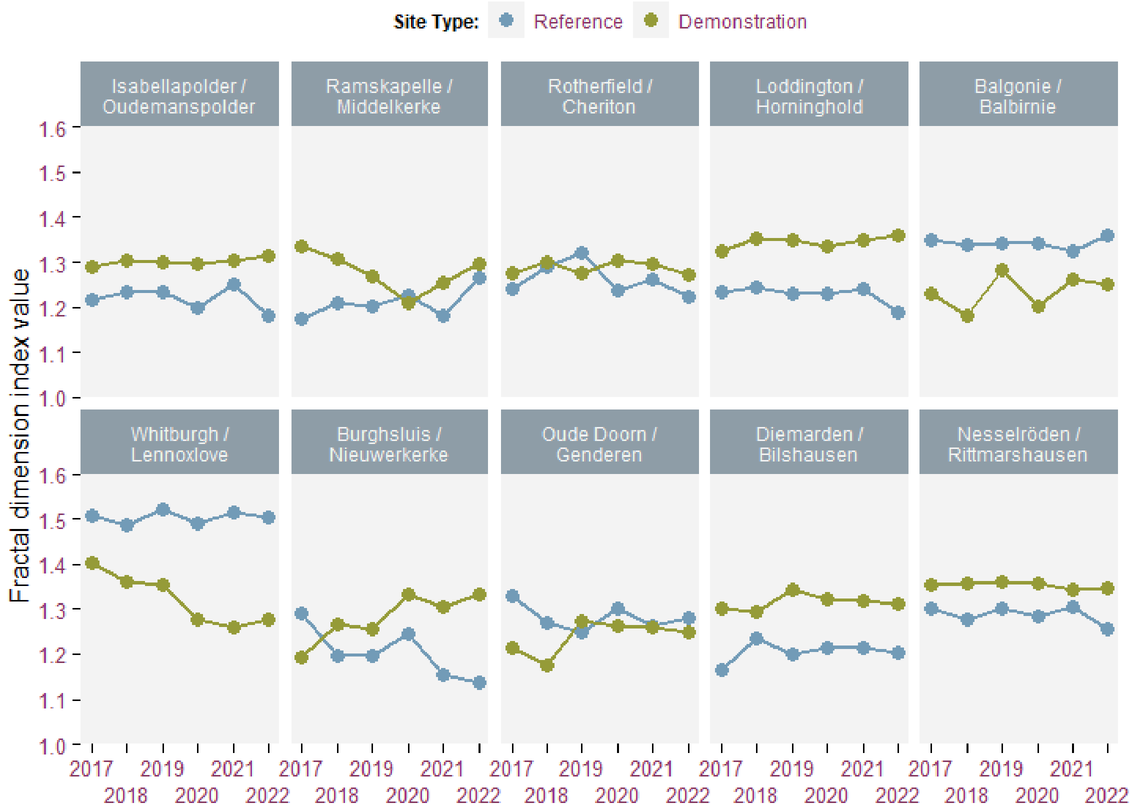


Figure A2-56: Changes over time in the fractal dimension index values of overwinter cover habitat at our project sites.

Lastly, we were also unable to detect a significant interaction between time and site type on the mean fractal dimension index values of overwinter cover habitat patches at our project sites ($F_{(1, 98)}$ = 2.20, p = 0.141, Figure A2-56). Values were not found to differ significantly between demonstration and reference sites ($F_{(1, 9)}$ = 0.58, p = 0.455). Finally, these values were not found to have changed significantly over the duration of the project ($F_{(1, 98)}$ = 0.45, p = 0.504).

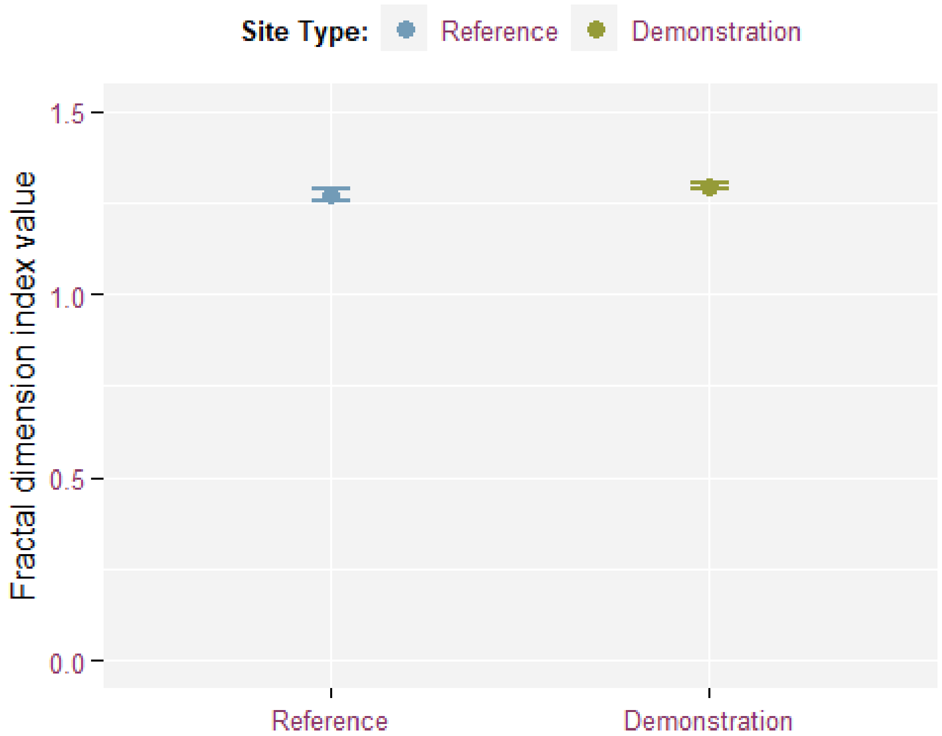


Figure A2-57: The difference in the average fractal dimension index of overwinter cover habitat of our project sites in the final three years of the project (2020 - 2022).

Core area index

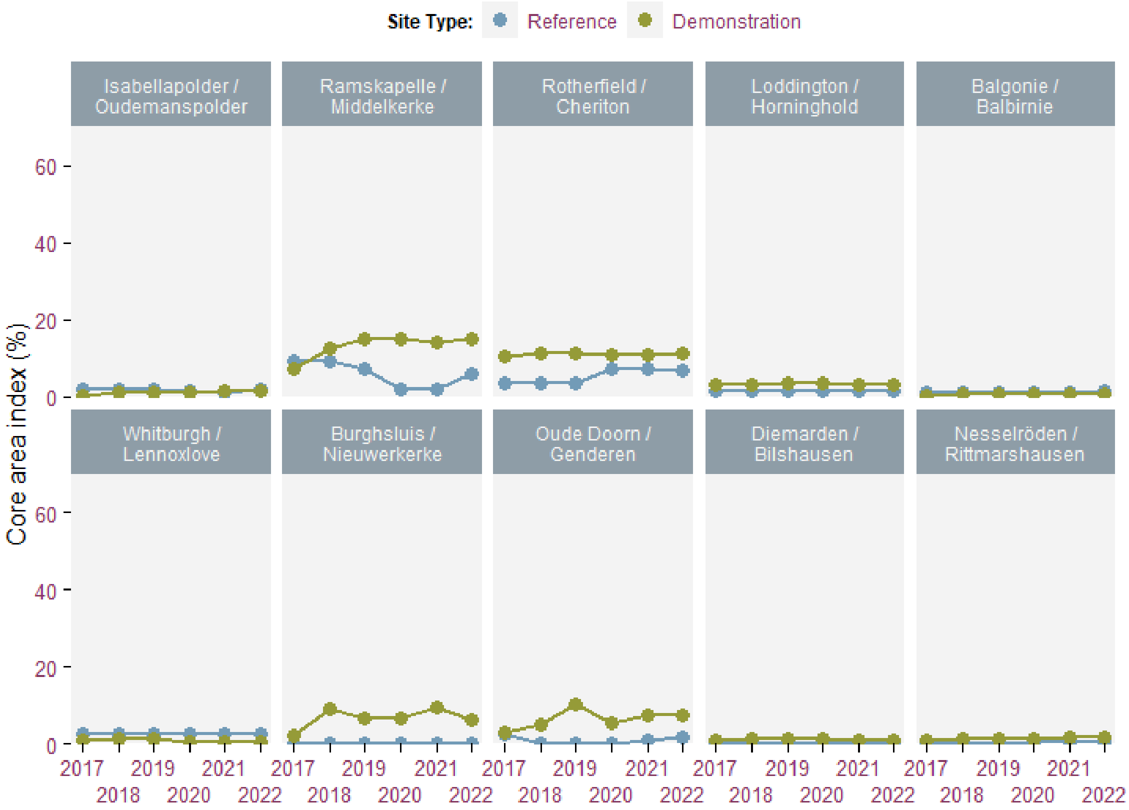


Figure A2-58: Changes over time in the core area index values of nesting habitat at our project sites.

We were unable to detect a significant interaction between site type and time on the core area index of nesting habitat at our project sites ($F_{(1, 98)}$ = 3.37, *p* = 0.069, Figure A2-58). The average core area index values of demonstration site were not found to be significantly different to those at reference sites ($F_{(1, 9)}$ = 4.98, *p* = 0.053). We were also unable to detect that these values changed significantly over time ($F_{(1, 98)}$ = 4.64, *p* = 0.034).

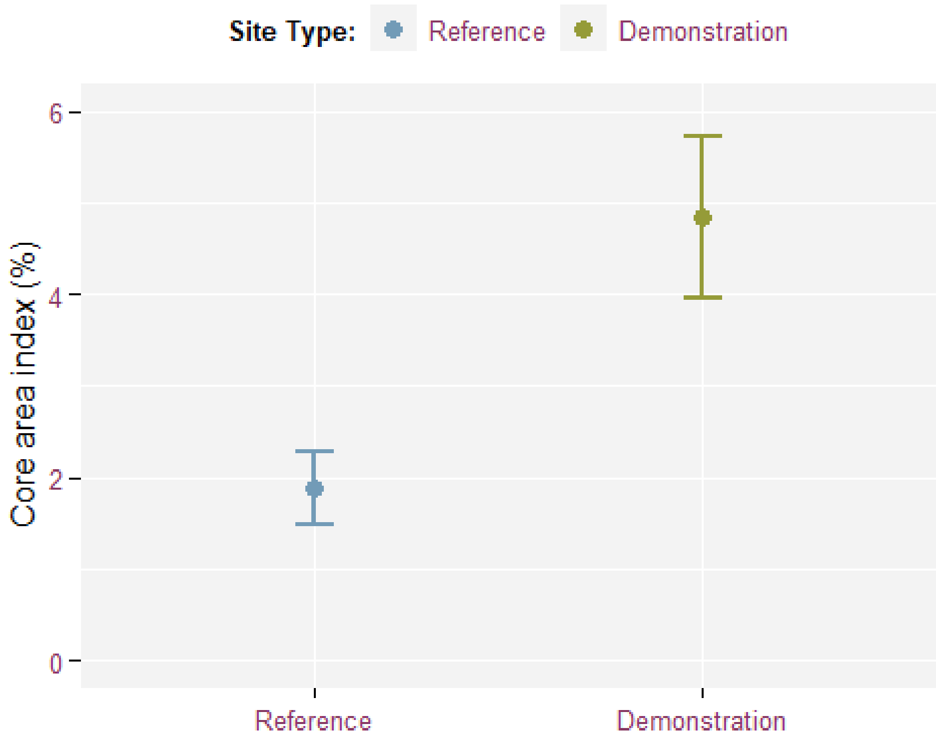


Figure A2-59: The difference in the core area index of nesting habitat of our project sites in the final three years of the project (2020 - 2022). Note different y-axis to Figure A2-58.

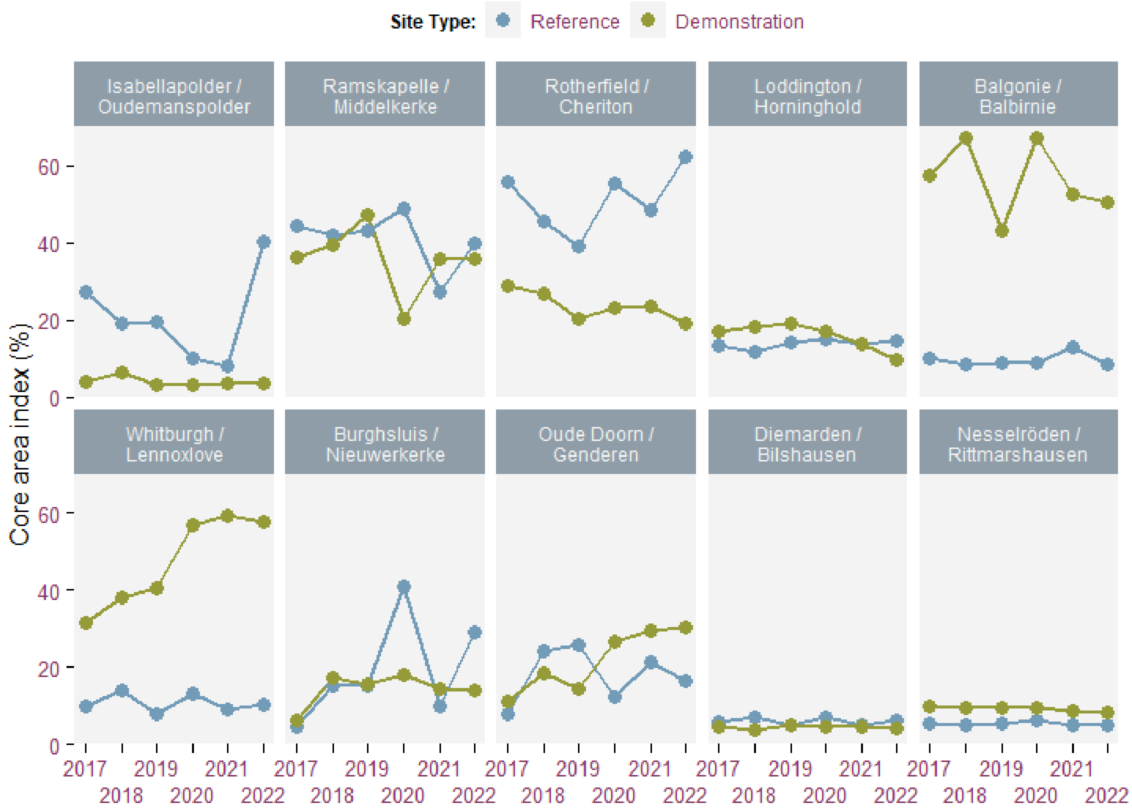


Figure A2-60: Changes over time in the core area index values of overwinter cover habitat at our project sites.

We were unable to detect a significant interaction between site type and time on the core area index values of overwinter cover habitat at our project sites ($F_{(1, 98)}$ = 0.03, p = 0.856, Figure A2-60). These values were not found to differ significantly between our demonstration and reference sites ($F_{(1, 9)}$ = 0.26, p = 0.620). These values were not found to have changed significantly throughout the duration of the project ($F_{(1, 98)}$ = 1.79, p= 0.184).

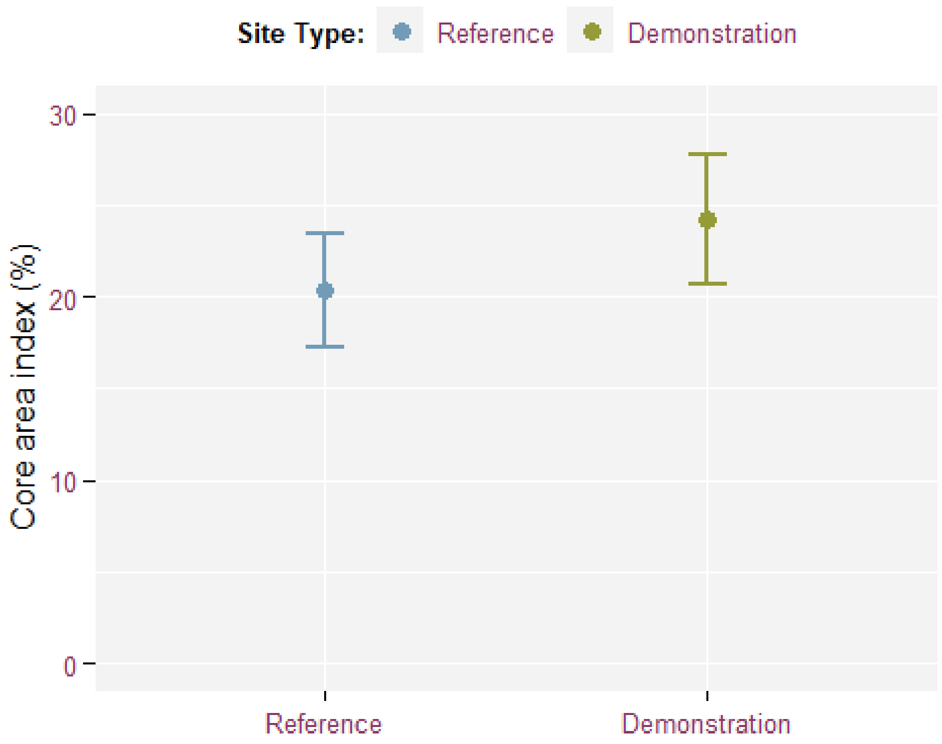


Figure A2-61: The difference in the core area index of overwinter cover habitat of our project sites in the final three years of the project (2020 - 2022). Note different y-axis to Figure A2-60.

Core area percentage of landscape

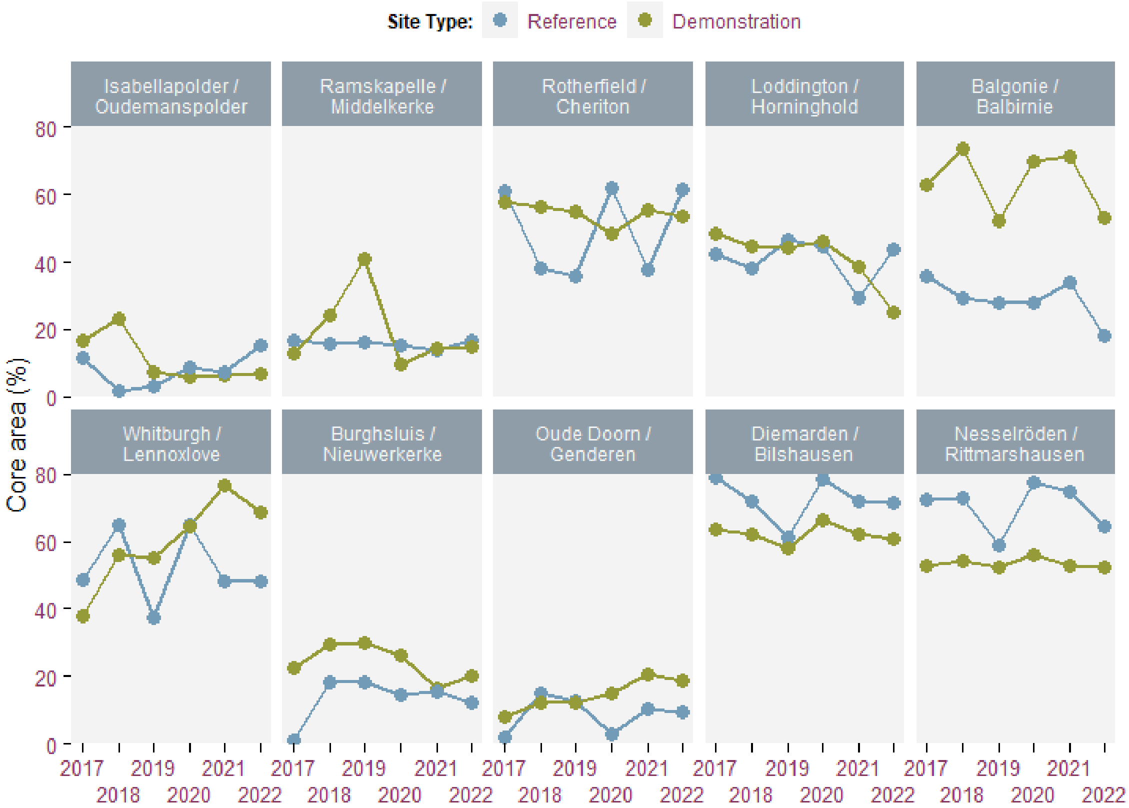


Figure A2-62: Changes over time in the percentage of the landscape occupied by core overwinter cover habitat at our project sites.

Lastly, we did not detect a significant interaction between site type and time on the percentage of the landscape occupied by overwinter cover habitat at our project sites ($F_{(1, 98)}$ = 0.39, *p* = 0.535, Figure A2-62). Unlike the case with nesting and brood-rearing cover, we did not detect that site type had a significant effect on these values ($F_{(1, 9)}$ = 1.48, *p* = 0.254). These values were not found to have changed significantly through time ($F_{(1, 98)}$ = 0.04, *p* = 0.845).

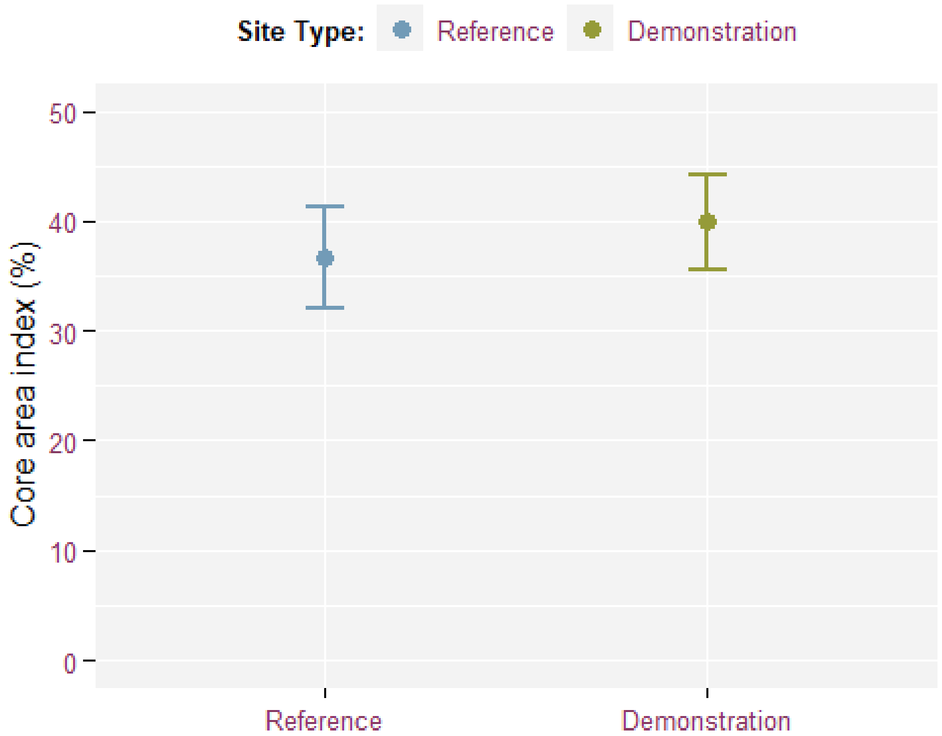


Figure A2-63: The average area (%) of the landscape occupied by core overwinter cover habitat on the reference and demonstration areas in the final three years of the project (2020 - 2022).

Appendix 3 – Site maps:

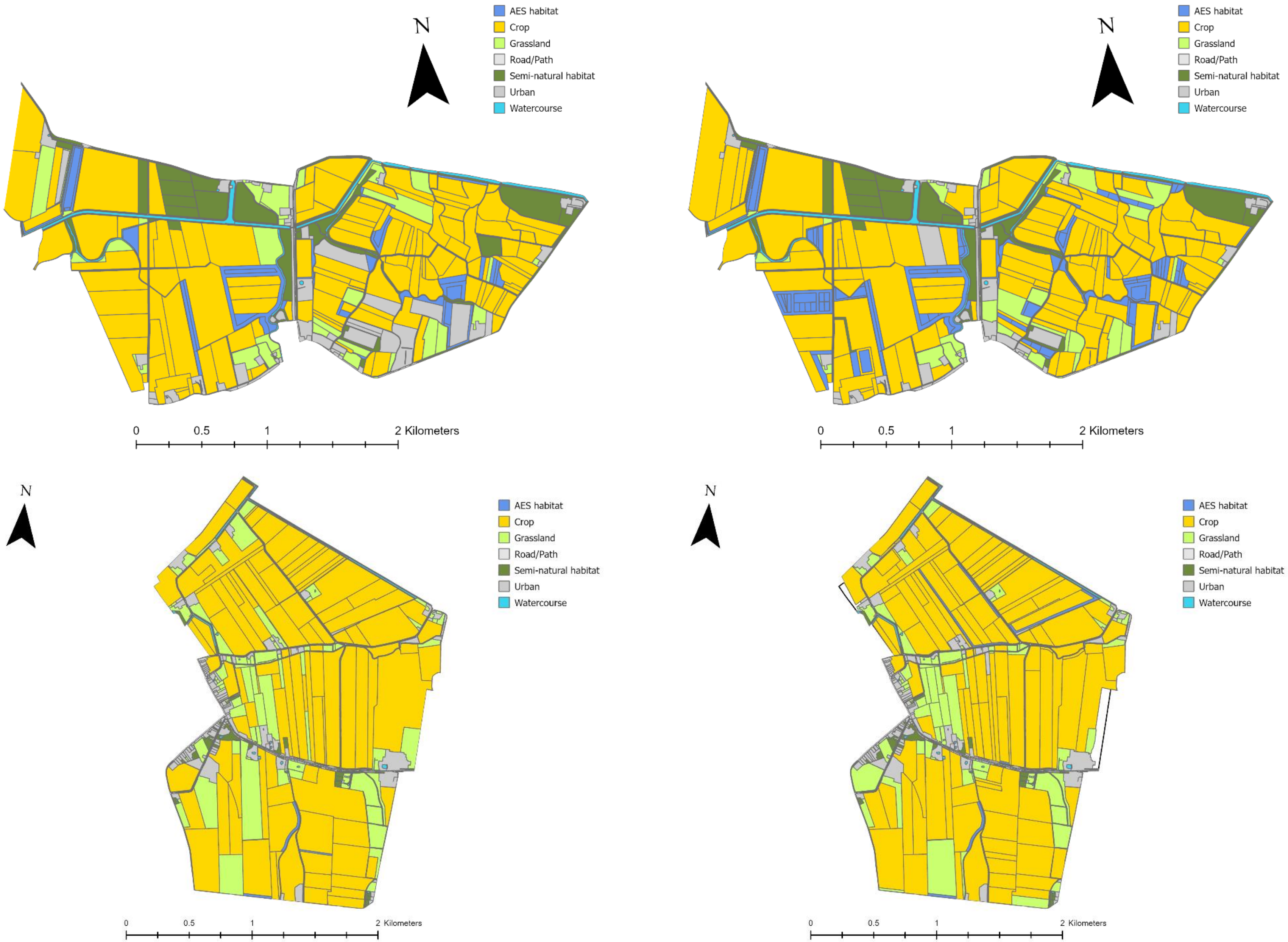


Figure A3-1: Maps of general habitat features (i.e., crops, grassland, semi-natural habitat) at the Isabellapolder demonstration site (top) and its paired reference site Oudemanspolder (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

Figure A3-2: Maps of beneficial habitat features (e.g., wild-bird mixes, beetle banks, pollen & nectar mixes) at the Isabellapolder demonstration site (top) and its paired reference site Oudemanspolder (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

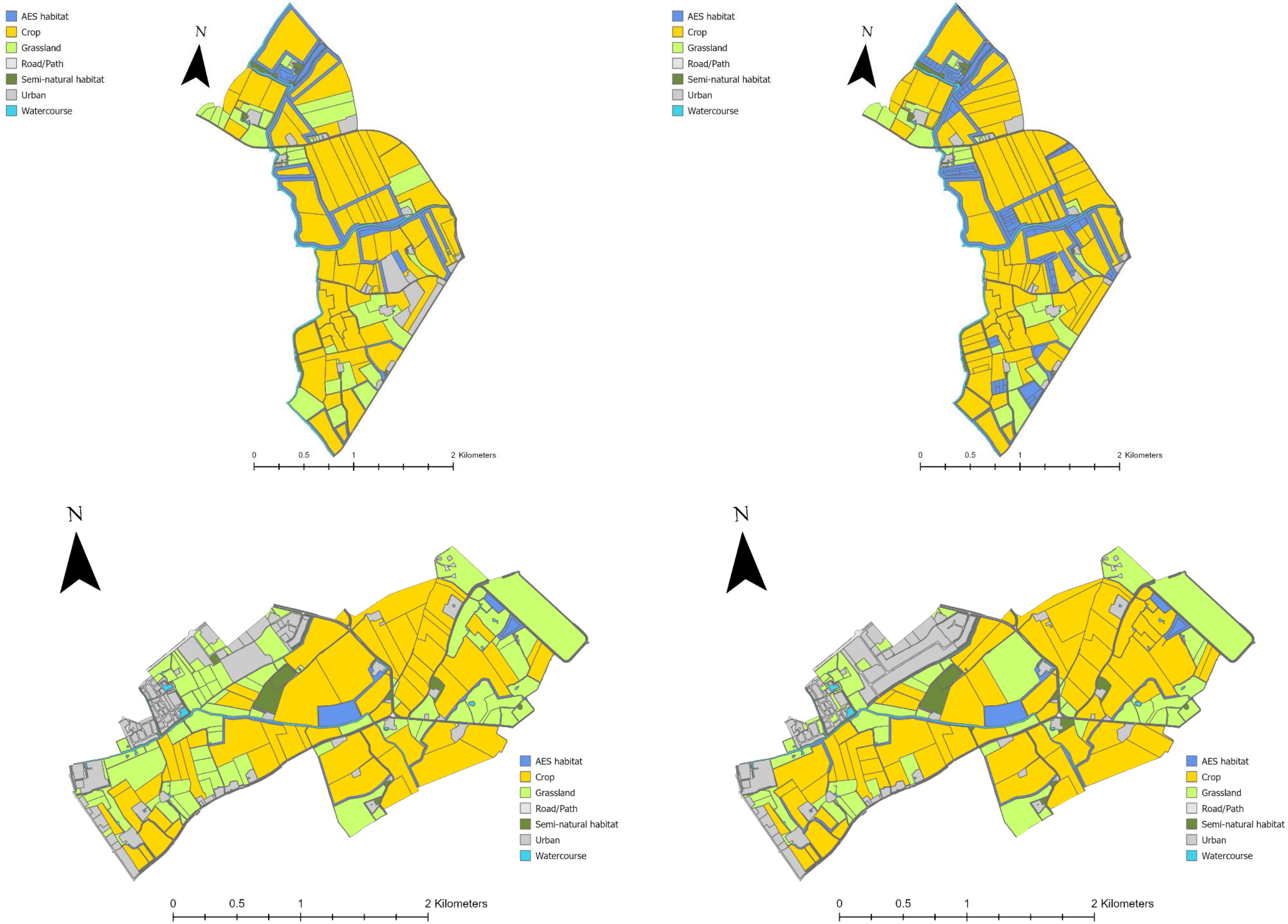


Figure A3-3: Maps of general habitat features (i.e., crops, grassland, semi-natural habitat) at the Ramskapelle demonstration site (top) and its paired reference site Middelkerke (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

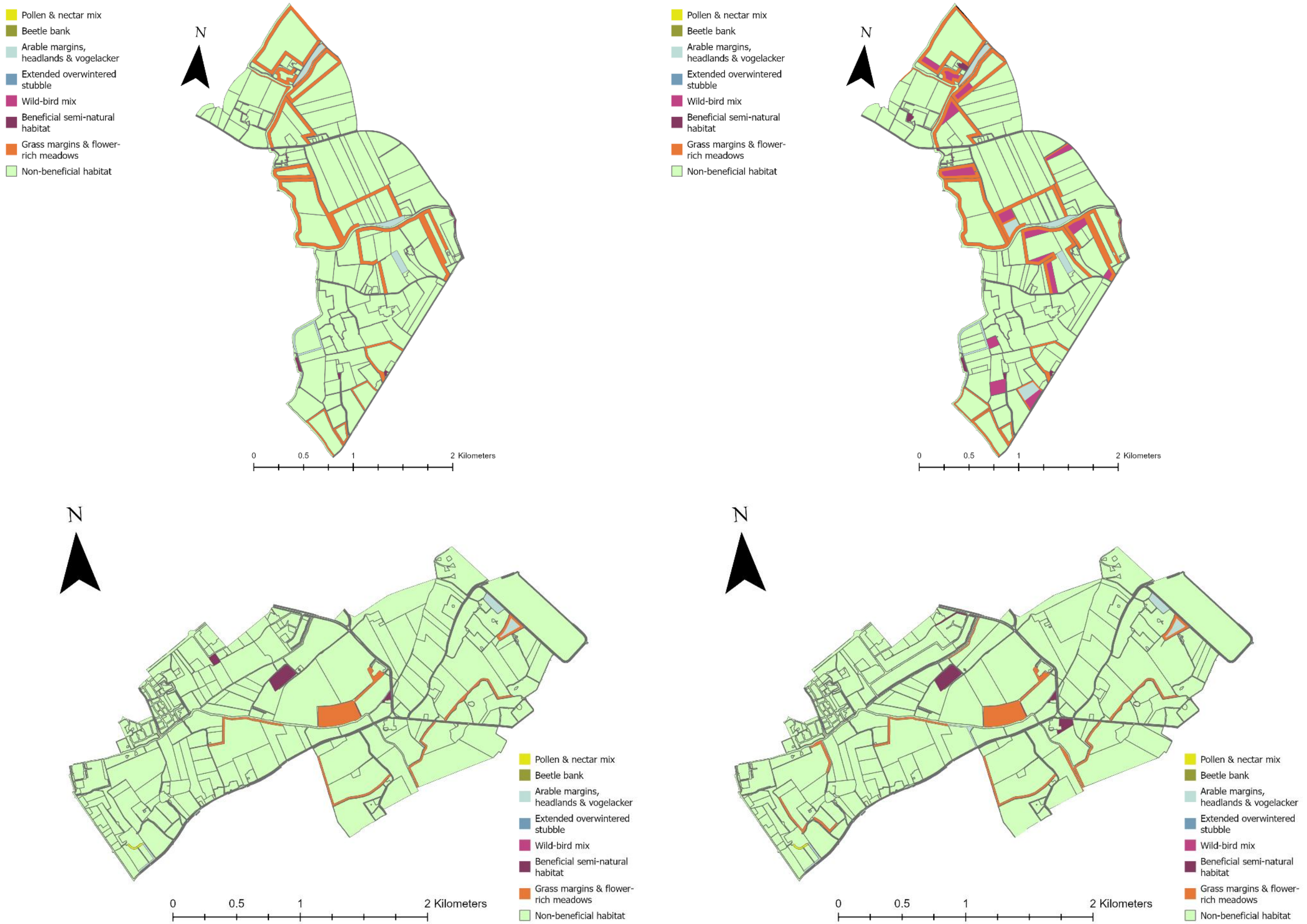


Figure A3-4: Maps of beneficial habitat features (e.g., wild-bird mixes, beetle banks, pollen & nectar mixes) at the Ramskapelle demonstration site (top) and its paired reference site Middelkerke (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

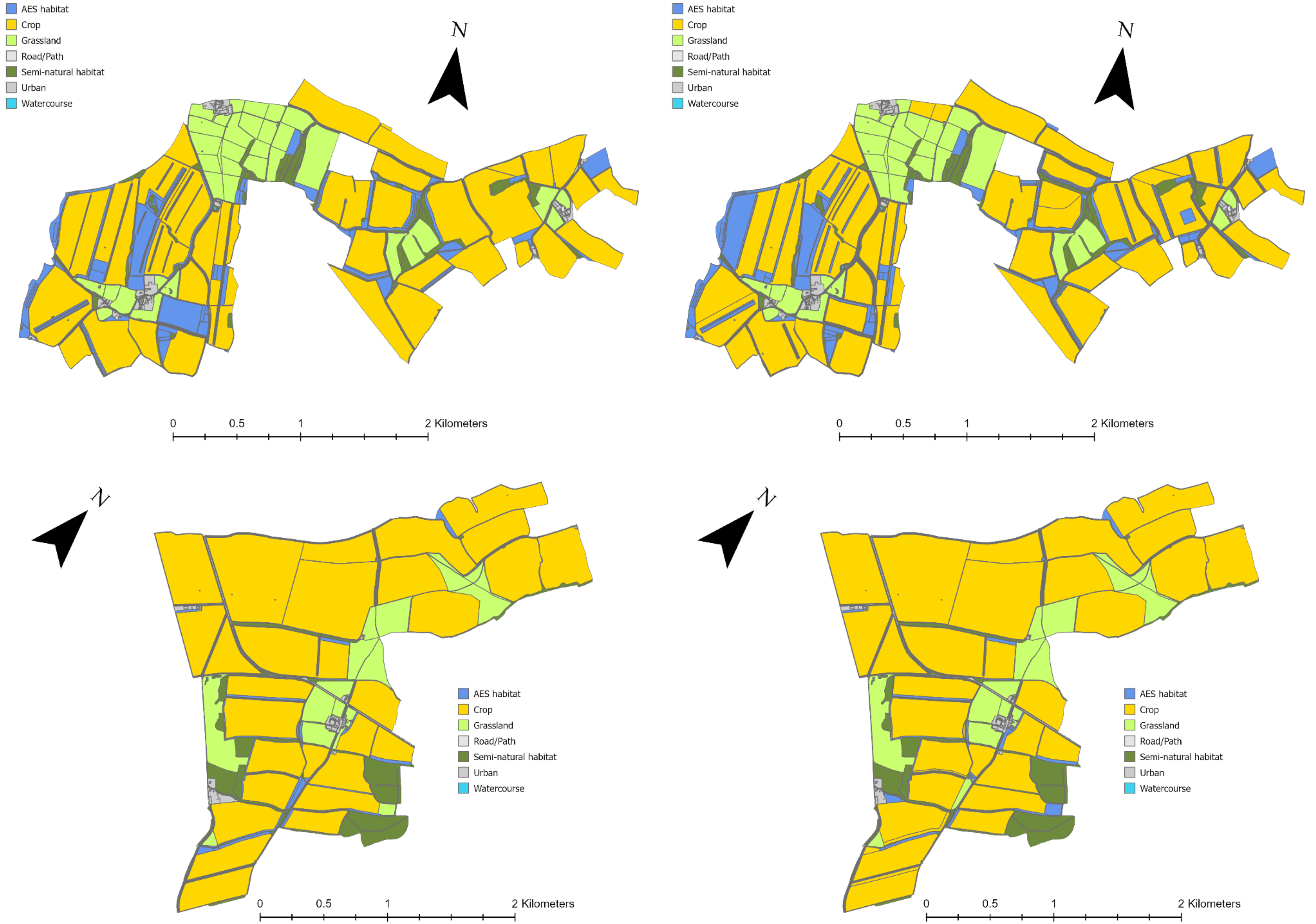


Figure A3-5: Maps of general habitat features (i.e., crops, grassland, semi-natural habitat) at the Rotherfield demonstration site (top) and its paired reference site Cheriton (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

Figure A3-6: Maps of beneficial habitat features (e.g., wild-bird mixes, beetle banks, pollen & nectar mixes) at the Rotherfield demonstration site (top) and its paired reference site Cheriton (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

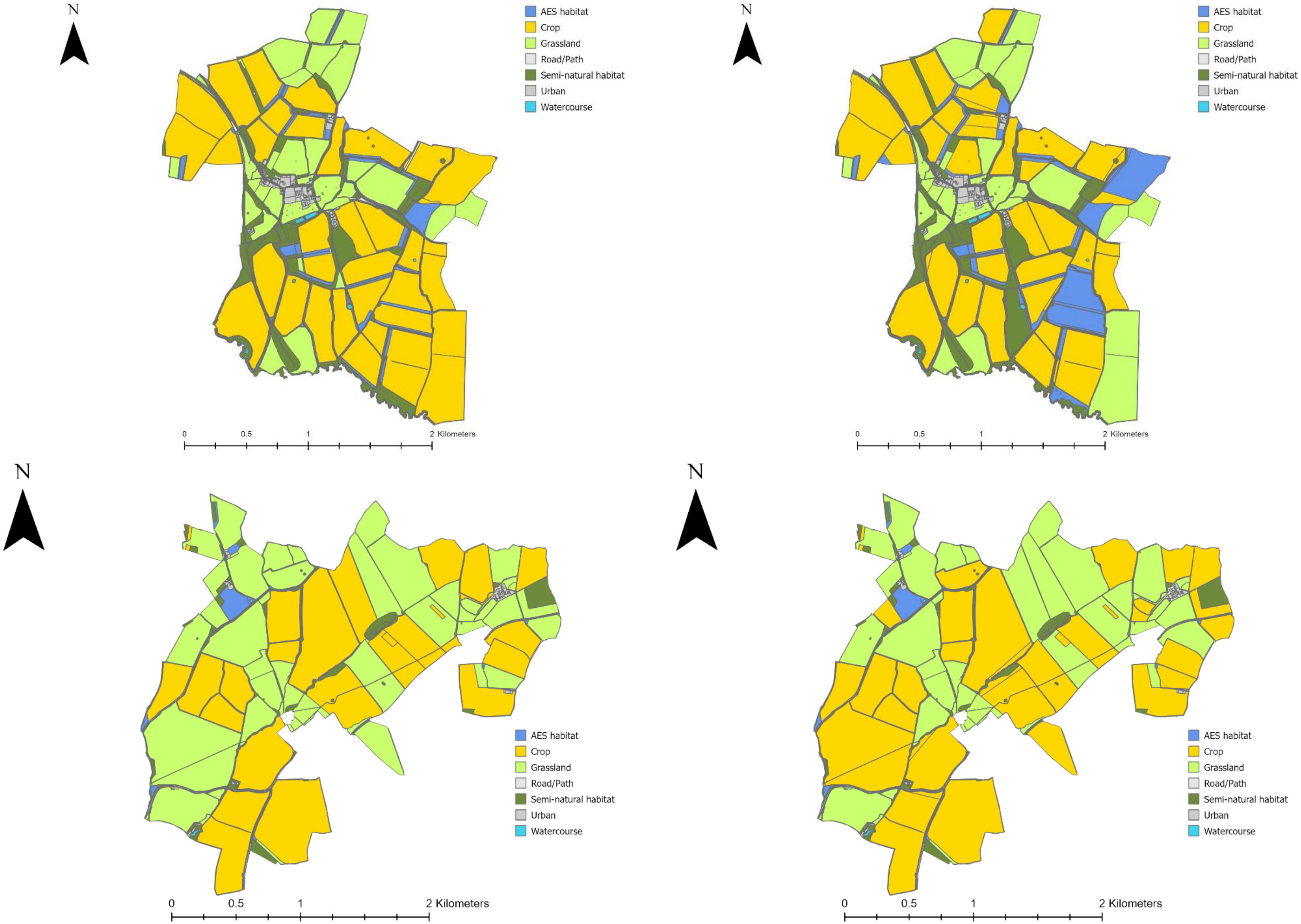


Figure A3-7: Maps of general habitat features (i.e., crops, grassland, semi-natural habitat) at the Loddington demonstration site (top) and its paired reference site Horninghold (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

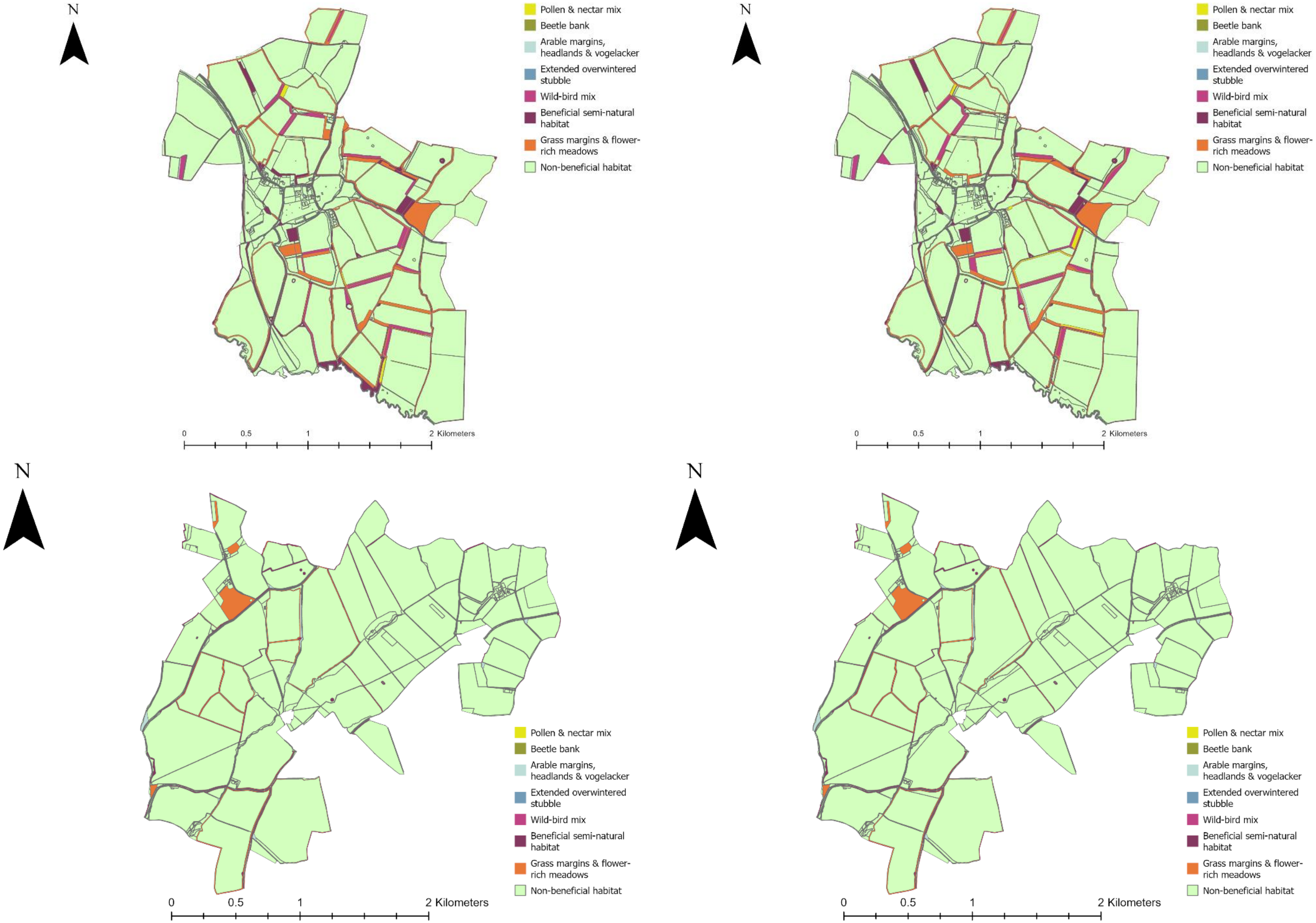


Figure A3-8: Maps of beneficial habitat features (e.g., wild-bird mixes, beetle banks, pollen & nectar mixes) at the Loddington demonstration site (top) and its paired reference site Horninghold (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

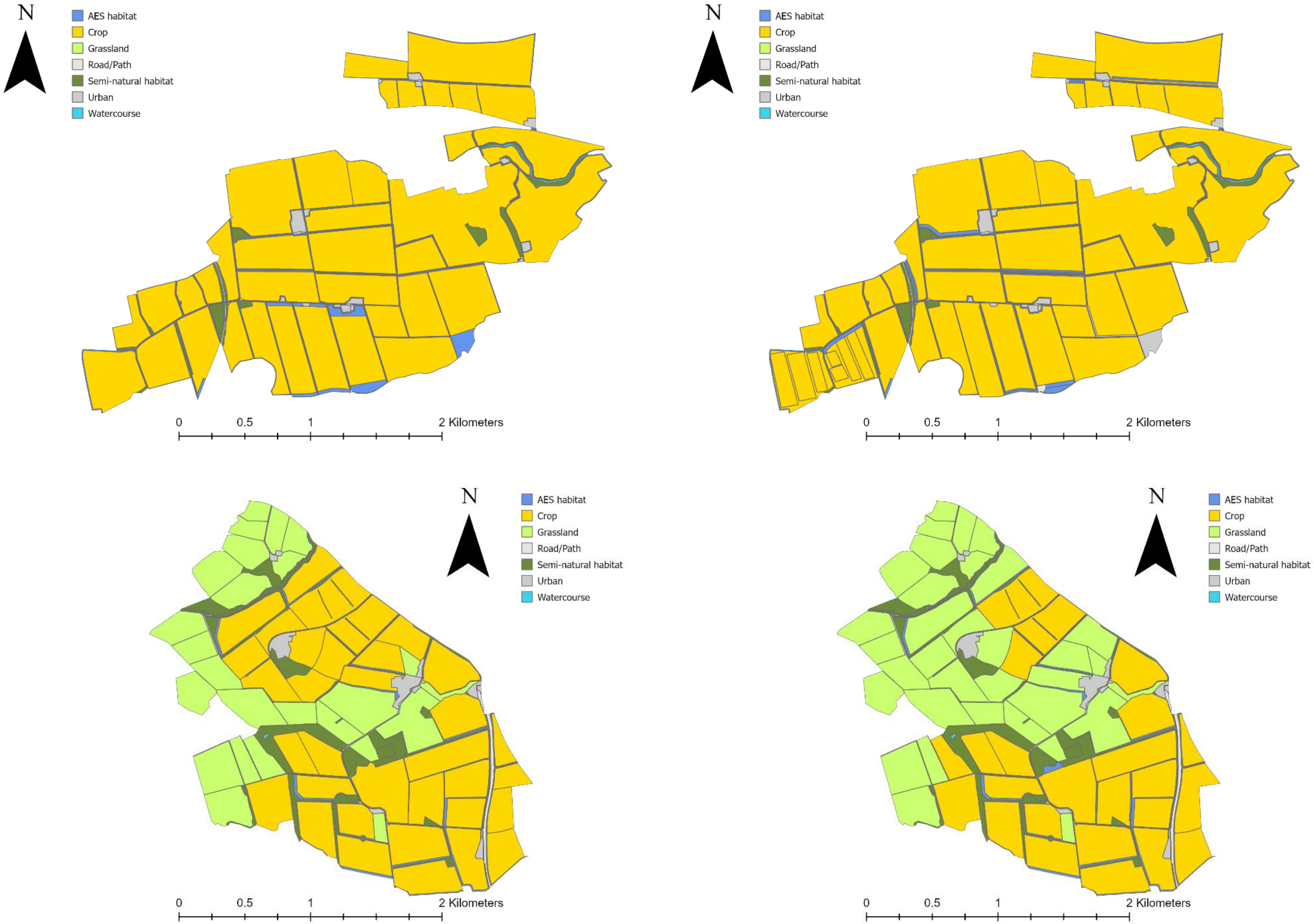


Figure A3-9: Maps of general habitat features (i.e., crops, grassland, semi-natural habitat) at the Balgonie demonstration site (top) and its paired reference site Balbirnie (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

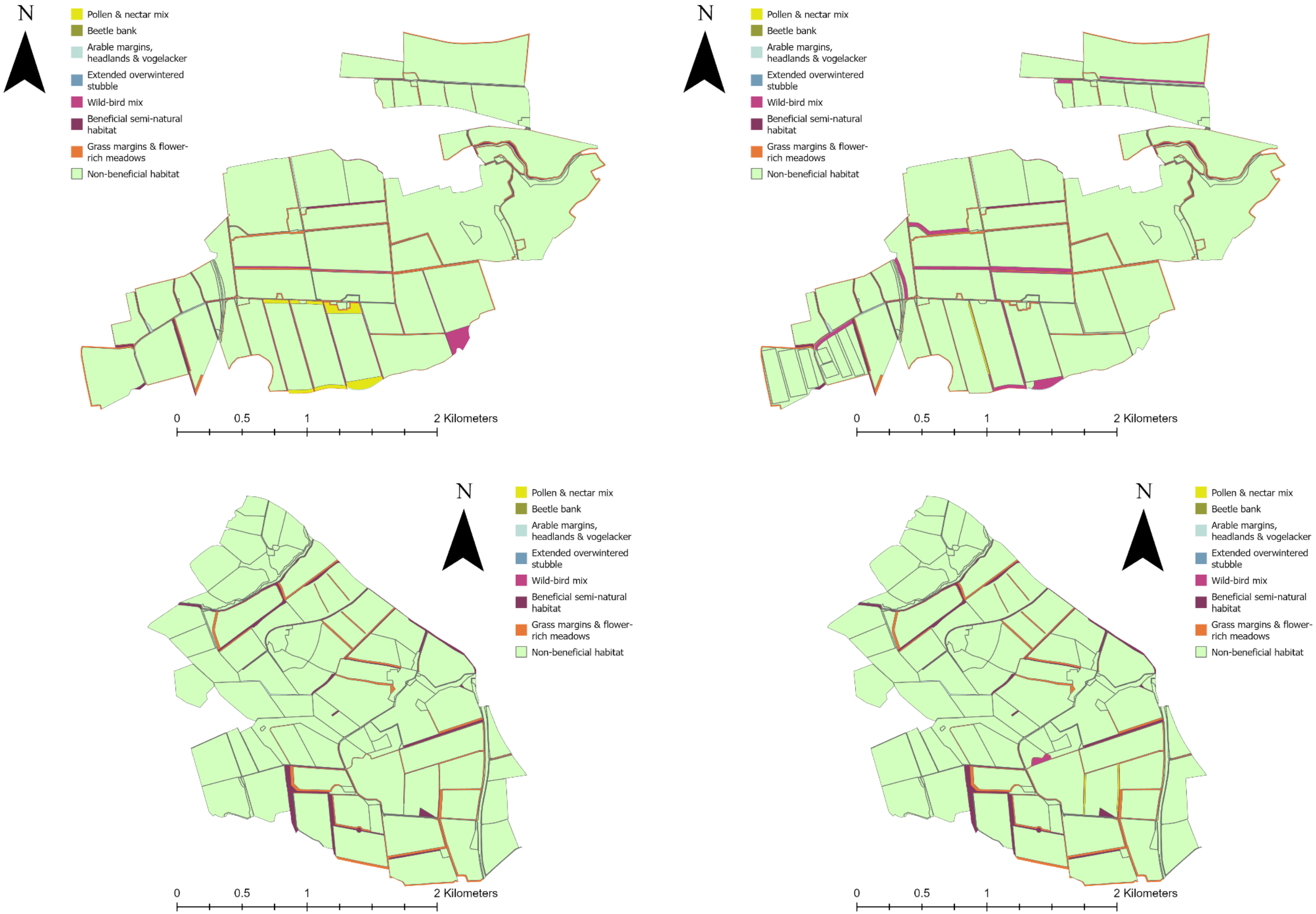


Figure A3-10: Maps of beneficial habitat features (e.g., wild-bird mixes, beetle banks, pollen & nectar mixes) at the Balgonie demonstration site (top) and its paired reference site Balbirnie (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

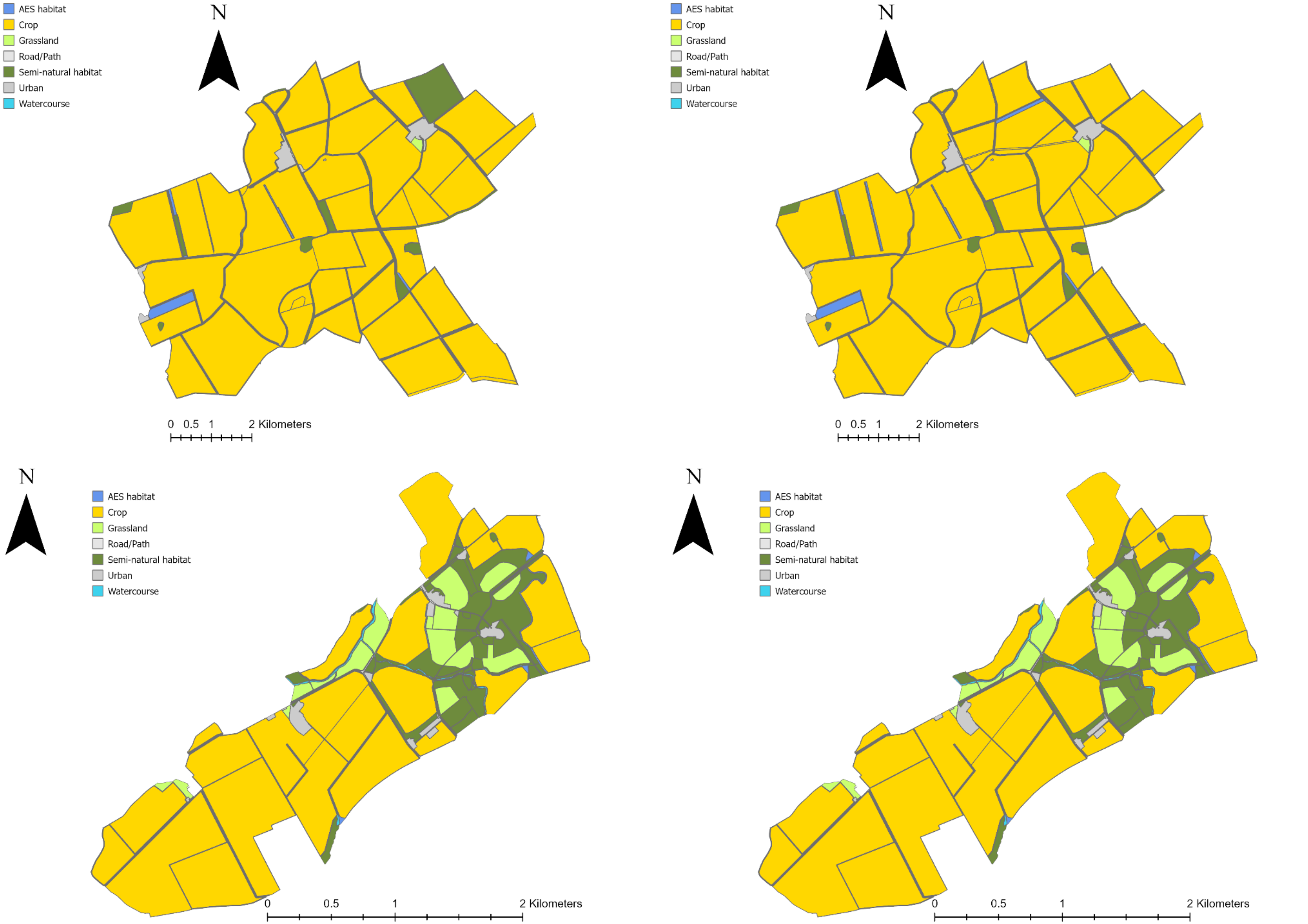


Figure A3-11: Maps of general habitat features (i.e., crops, grassland, semi-natural habitat) at the Whitburgh demonstration site (top) and its paired reference site Lennoxlove (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

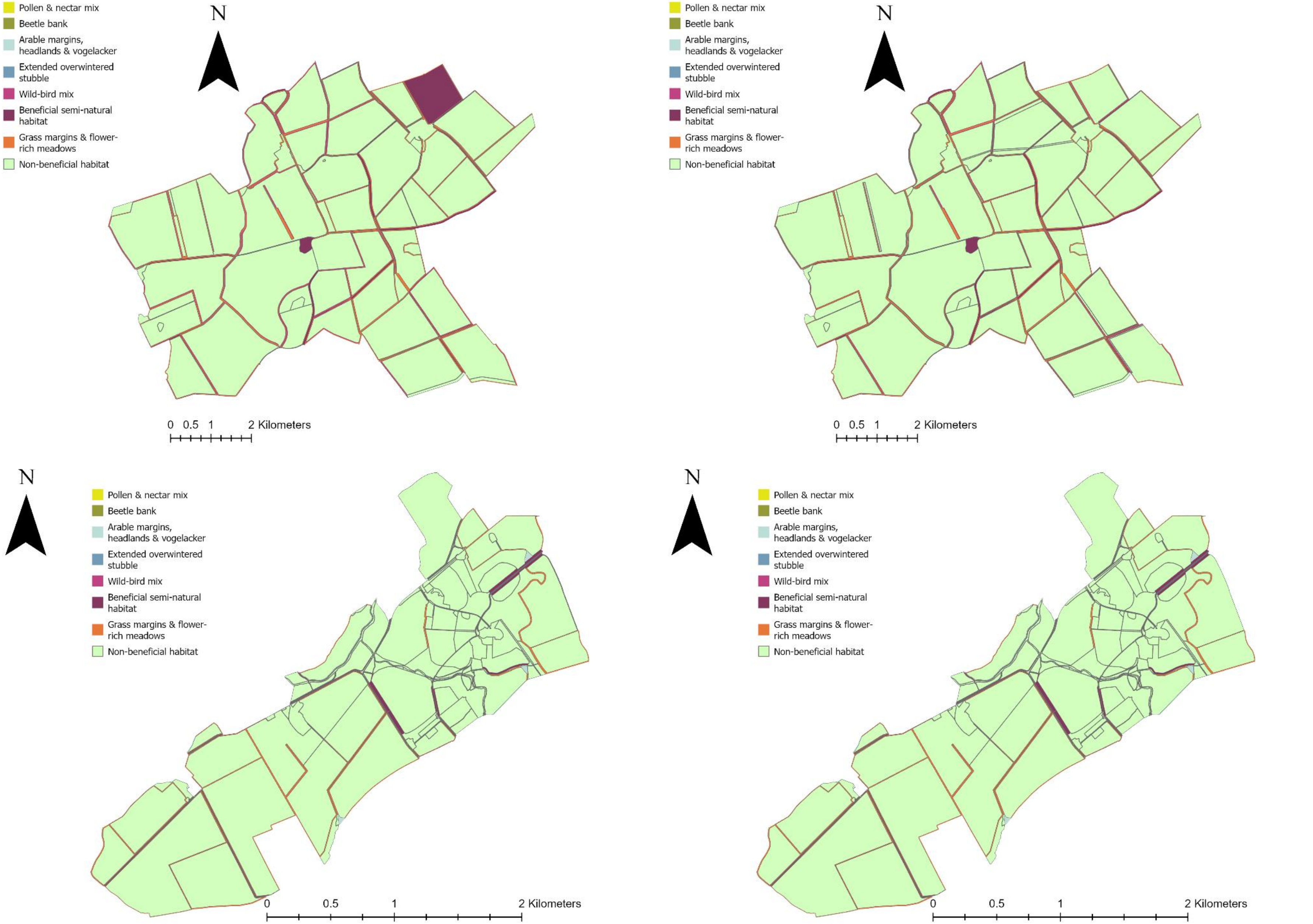


Figure A3-12: Maps of beneficial habitat features (e.g., wild-bird mixes, beetle banks, pollen & nectar mixes) at the Whitburgh demonstration site (top) and its paired reference site Lennoxlove (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

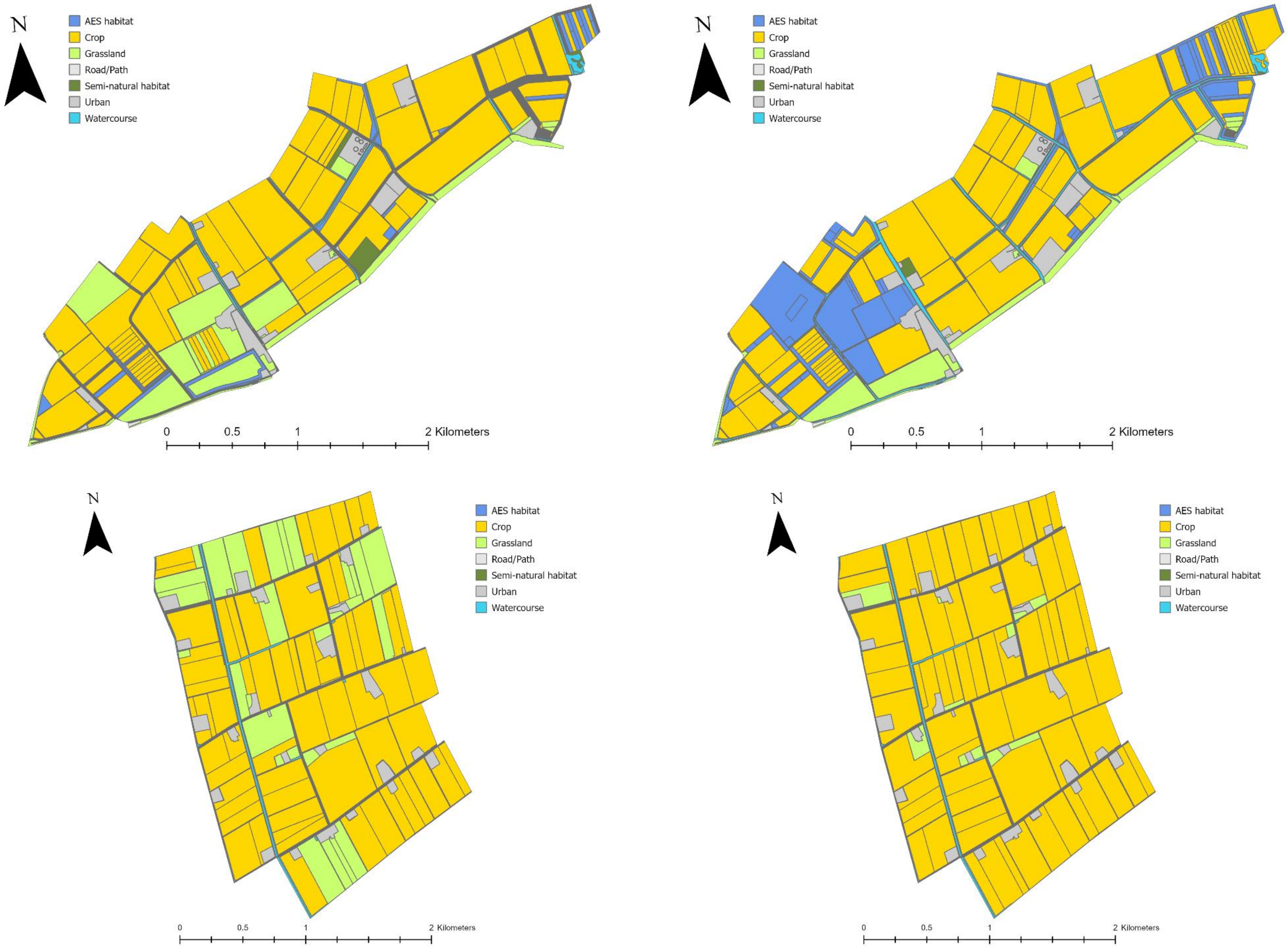


Figure A3-13: Maps of general habitat features (i.e., crops, grassland, semi-natural habitat) at the Burghsluis demonstration site (top) and its paired reference site Nieuwerkerke (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

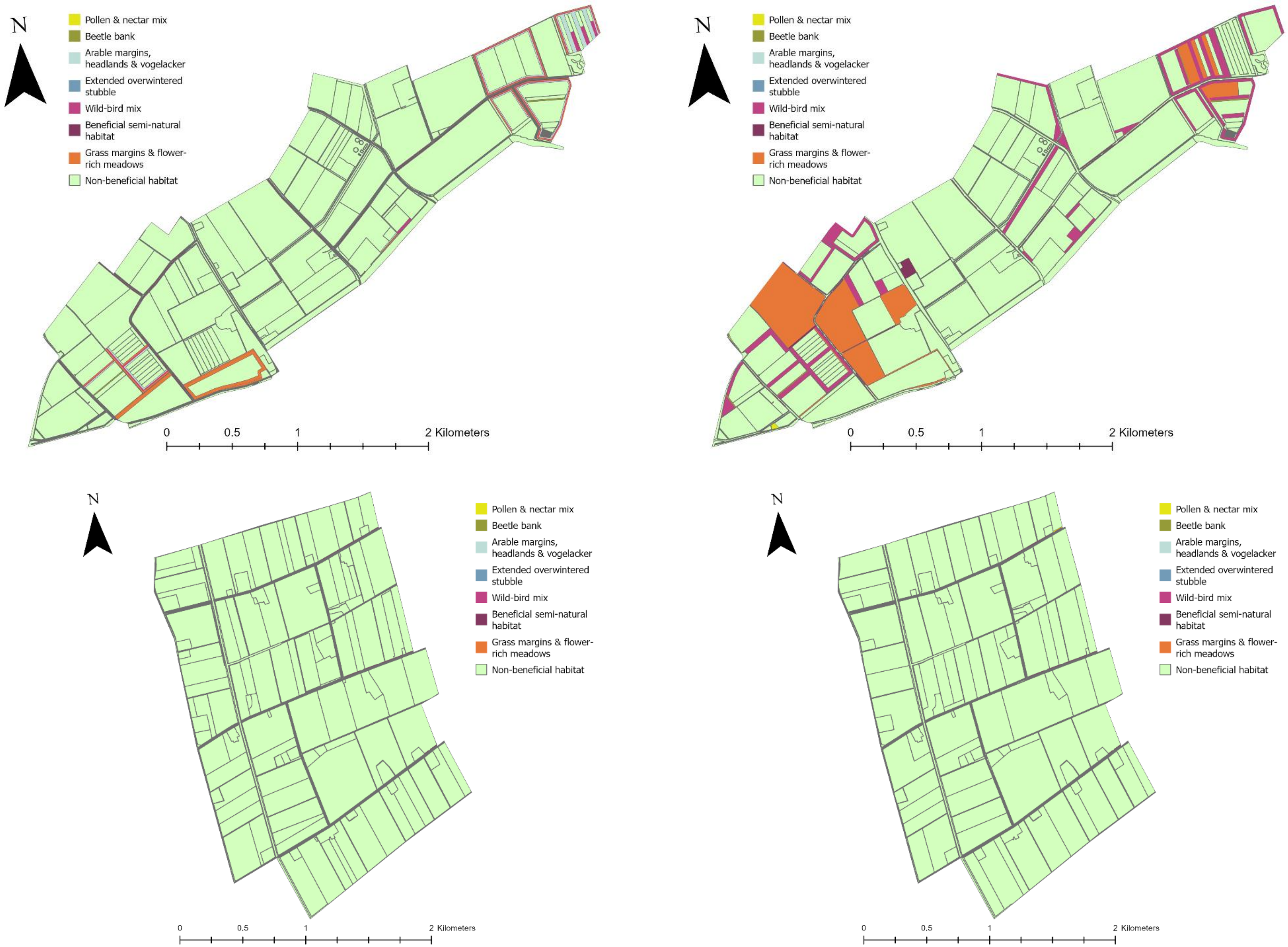


Figure A3-14: Maps of beneficial habitat features (e.g., wild-bird mixes, beetle banks, pollen & nectar mixes) at the Burghsluis demonstration site (top) and its paired reference site Nieuwerkerke (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

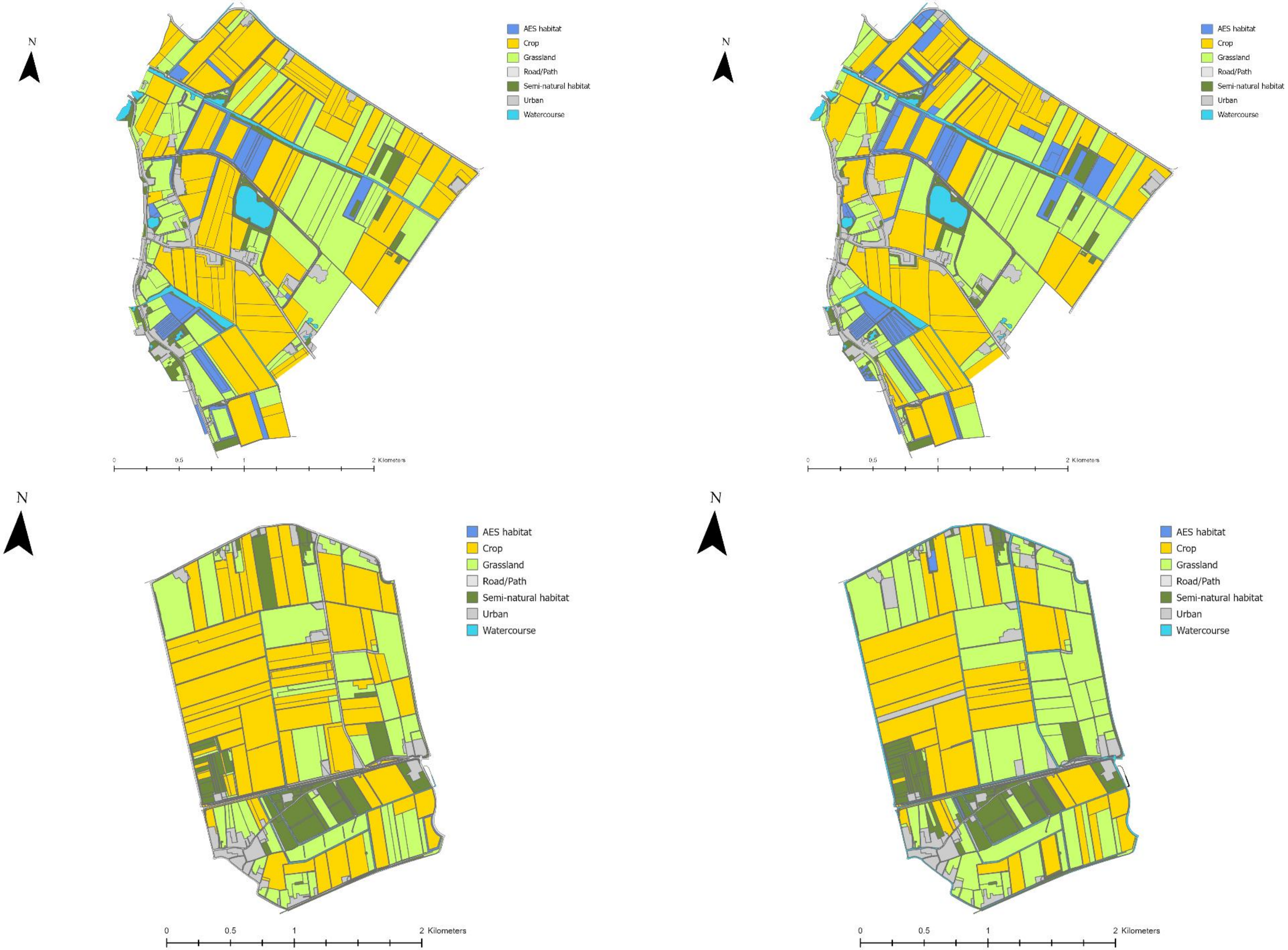


Figure A3-15: Maps of general habitat features (i.e., crops, grassland, semi-natural habitat) at the Oude Doorn demonstration site (top) and its paired reference site Genderen (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

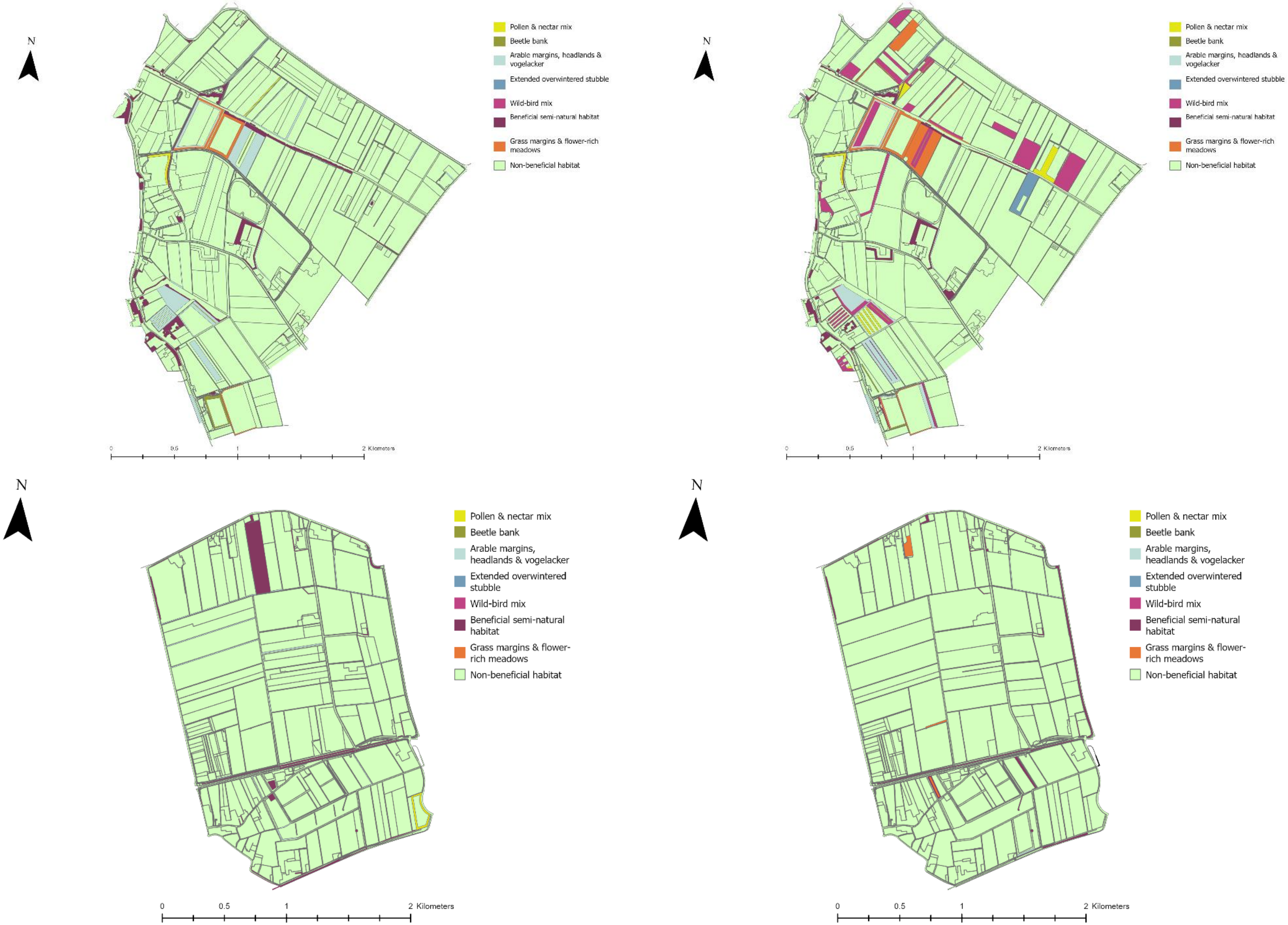


Figure A3-16: Maps of beneficial habitat features (e.g., wild-bird mixes, beetle banks, pollen & nectar mixes) at the Oude Doorn demonstration site (top) and its paired reference site Genderen (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

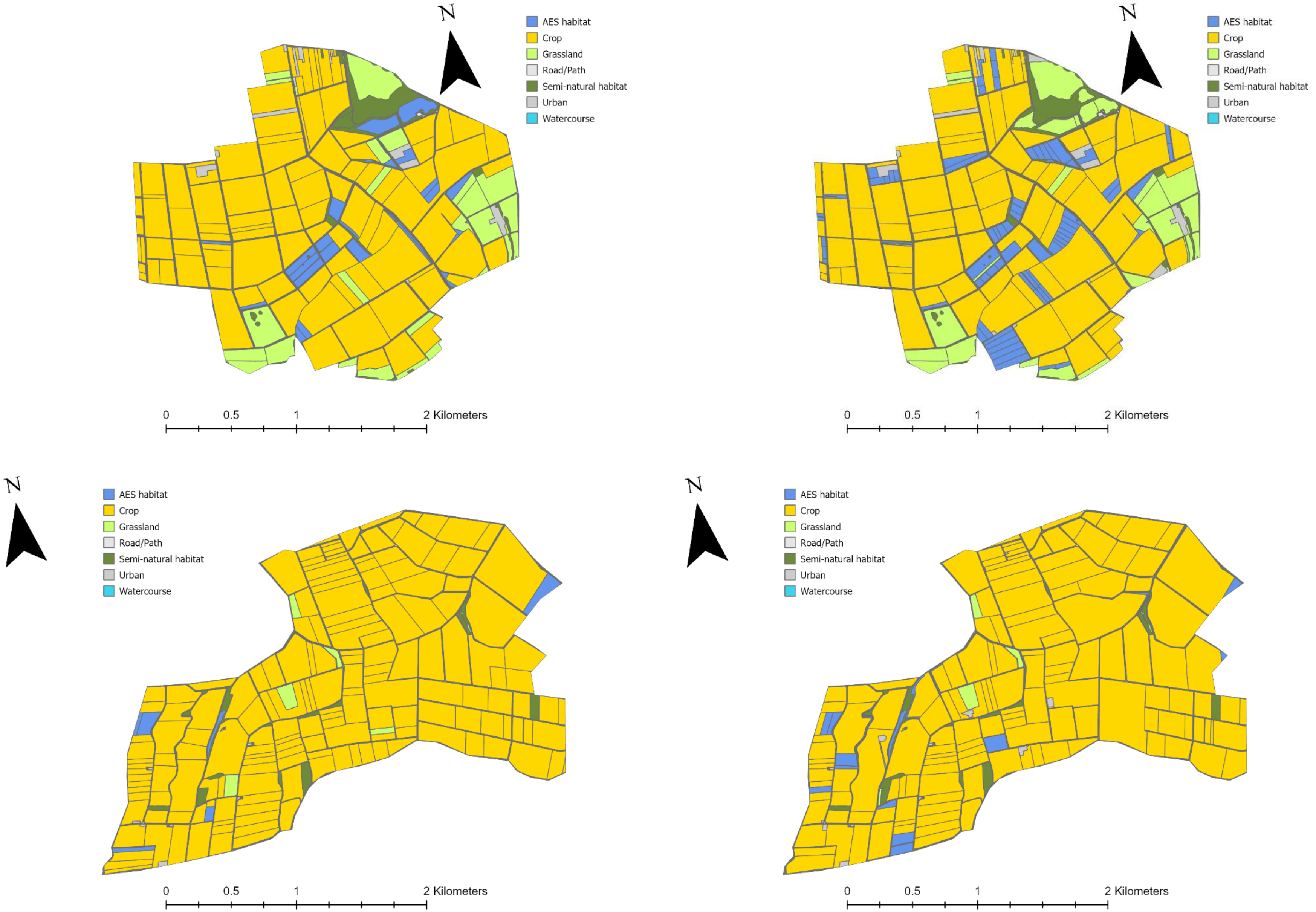


Figure A3-17: Maps of general habitat features (i.e., crops, grassland, semi-natural habitat) at the Diemarden demonstration site (top) and its paired reference site Bilshausen (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

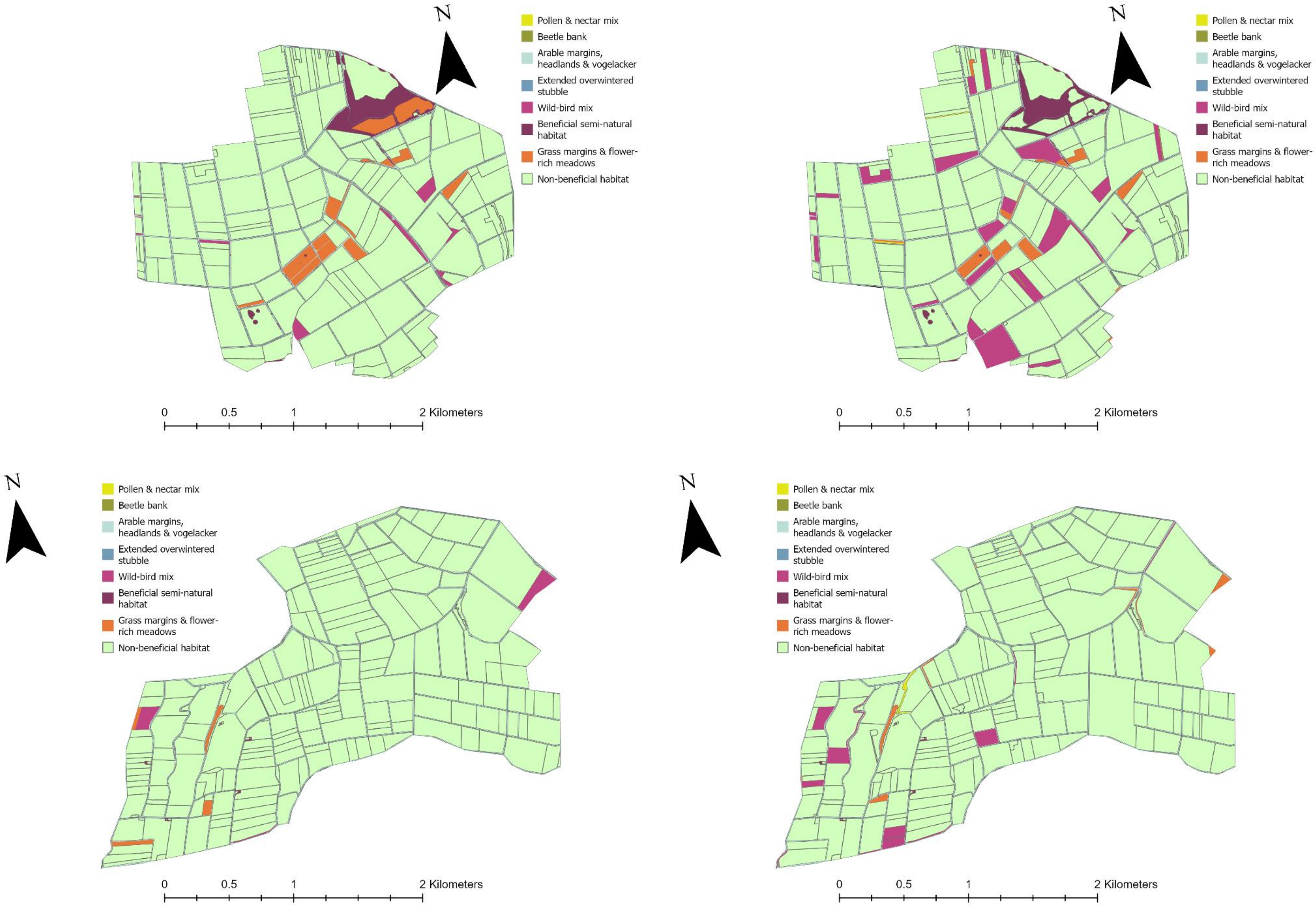


Figure A3-18: Maps of beneficial habitat features (e.g., wild-bird mixes, beetle banks, pollen & nectar mixes) at the Diemarden demonstration site (top) and its paired reference site Bilshausen (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

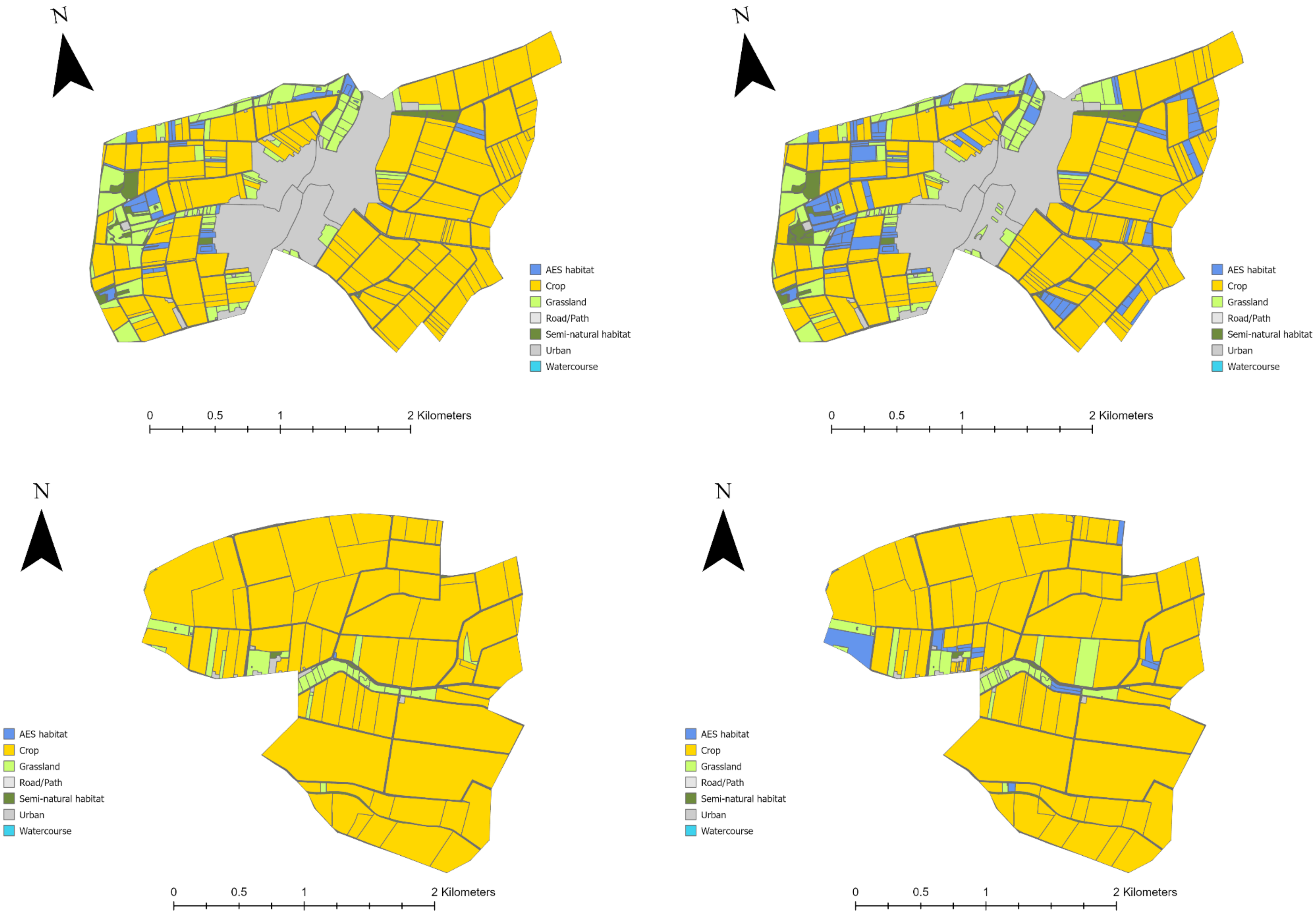


Figure A3-19: Maps of general habitat features (i.e., crops, grassland, semi-natural habitat) at the Nesselröden demonstration site (top) and its paired reference site Rittmarshausen (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.

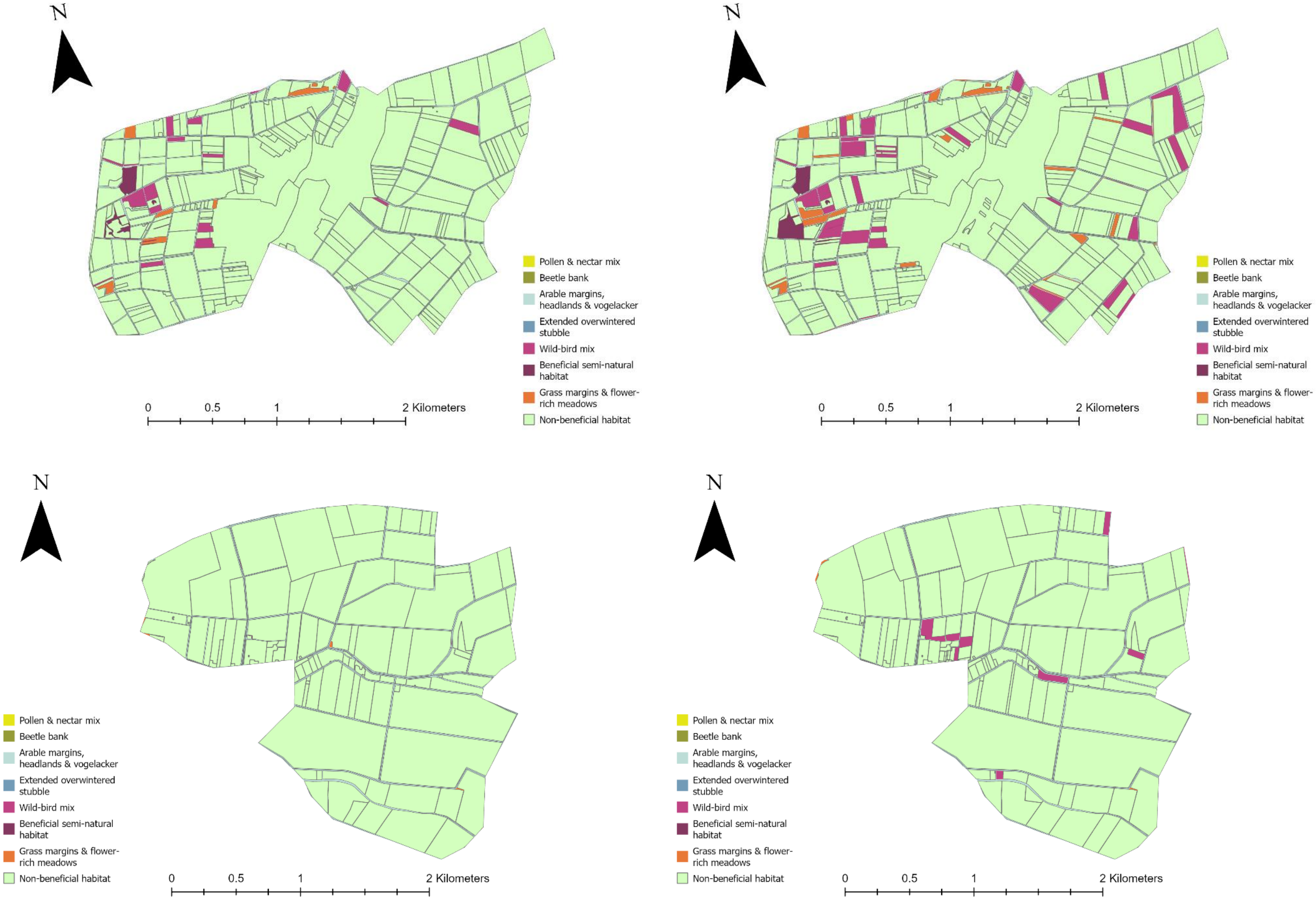


Figure A3-20: Maps of beneficial habitat features (e.g., wild-bird mixes, beetle banks, pollen & nectar mixes) at the Nesselröden demonstration site (top) and its paired reference site Rittmarshausen (bottom). Maps illustrate these features at the onset of the project in 2017 (left) and the end of the project in 2022 (right). Note that map scales may differ between project sites.