INCLUSIEF
NEDERLANDSE
SAMENVATTING
ÉN **AANBEVELINGEN**

Turtle Doves in a Changing Landscape

Gaining Insight into the Daily Movements of Turtle Doves in relation to the landscape

Report: 2019 - 2020

Jennifer Vreugdenhil – Rowlands
April 2021

Turtle Doves in a Changing Landscape

This final project report is an analysis of all the data collected in 2019 and 2020. It marks the end of the 2-year project "Turtle Doves in a Changing Landscape".

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Report Released: April 2021
Total Pages 105

Funded by:

Acknowledgements

Due to the complex situation of the turtle dove this project relies on the support and knowledge of many people, representing many organisations and institutions:

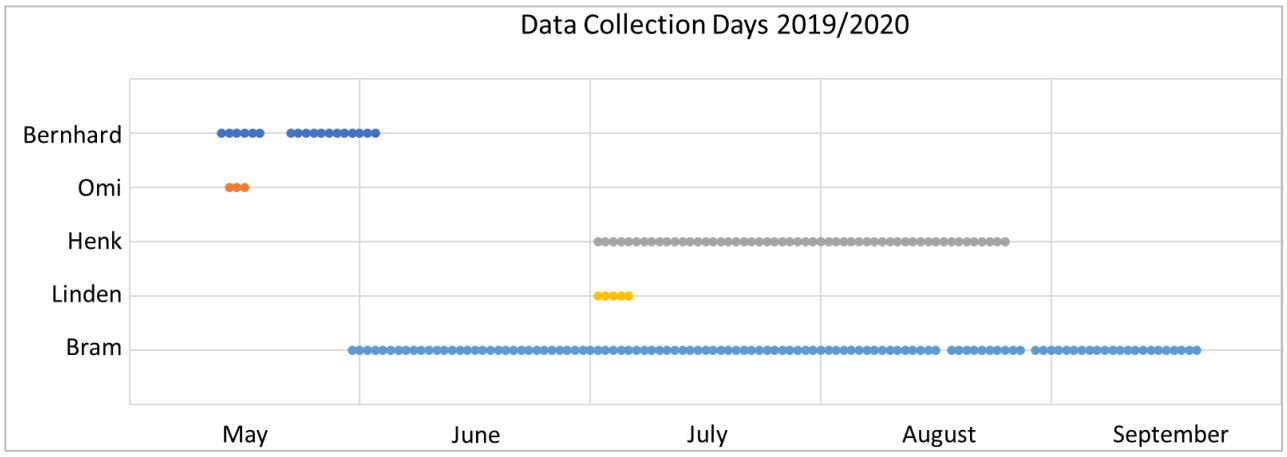
Volunteers 2019/2020: Chris Vreugdenhil, Elly Schipper, André Vreugdenhil, Co van den Boogerd, Vermin Family, Anita Hugense
Intern 2019: Naomi Oostinga
Private Landowners: Harry Visser (Schaapskooi Nisse), Vermin Family, Carla Jacobusse, Tractor Museum Nisse
Het Zeeuwse Landschap: Wannes Castelijns, Chiel Jacobusse, Chris Vreugdenhil, Hein Vermin
Justus Liebig University of Giessen: Petra Quillfeldt, Yvonne Schumm
Natuurmonumenten: Tijmen den Ottelander, Rene Wink, André Hannewijk
NIOO Vogeltrekstation: Henk van der Jeugd
Sovon: Erik Kleyheeg, Jan-Willem Vergeer
University of Groningen (RUG): Raymond Klaassen
Birdlife Netherlands: Jules Bos
RSPB: Guy Anderson, John Mallord, Samantha Lee
Wageningen University: Corné Vreugdenhil, Matthijs Boessenkool (GIS student)
Aviornis International Nederland: Charles van de Kerkhof

Table of Contents

Abstract (Nederlands)

De populatie van de zomertortel (*Streptopelia turtur*) is de afgelopen decennia sterk afgenomen in heel Europa. In Nederland is de broedpopulatie sinds de jaren '80 met meer dan 90% afgenomen en resteren minder dan 1200-1400 broedparen (Sovon 2015). De Europese Commissie heeft samen met verschillende partners een Internationaal Actieplan voor deze Rode Lijstsoort opgesteld. Hierin wordt onder andere de complexe internationale problematiek beschreven en worden kennislacunes voor effectieve bescherming aangegeven. Eén van deze kennislacunes betreft informatie over dagelijkse verplaatsingen en habitatgebruik in de broedgebieden.

Dit onderzoek is opgezet om inzicht te krijgen in het habitat- en landschapsgebruik van 5 zomertortels in de Zak van Zuid-Beveland (Zeeland, NL). Deze rapportage is een analyse van de gegevens uit de broedseizoenen 2019 en 2020 en focust op gebruik van het landschap en voorkeuren voor foerageerlocaties. Vijf zomertortels, allen man, waarvan één juveniel, zijn uitgerust met gps-telemetrie loggers die locaties met een vast interval vastleggen. Via de loggers en de 5 vogels zijn er in totaal 2450 punten verzameld en uitgelezen in de broedseizoenen 2019 en 2020.



GPS-Data collection: five turtle doves were followed using GPS-transmitters, each for a different period of time

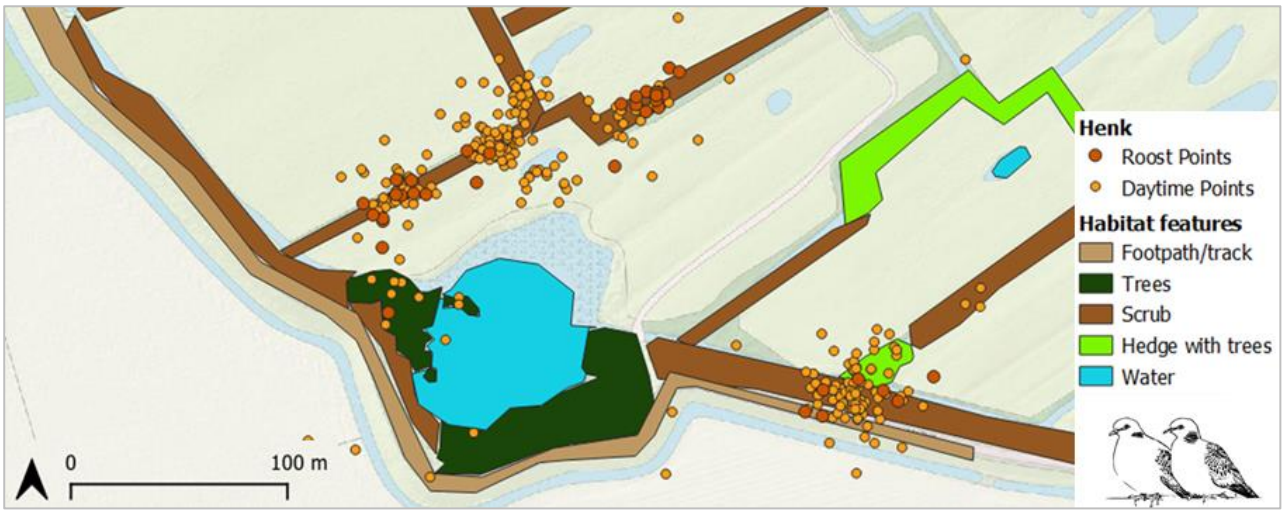
De analyse van deze gegevens levert inzicht op in het dagelijks gebruik van het landschap door de 5 tortels. In het rapport wordt ingegaan op 'home range', territoria en foerageer- en nesthabitat.

'Home range' (Hoofdstuk 4.1)

De 'home range' varieerde van 3,9 ha (juveniel) tot 1300 ha. Binnen deze home ranges, overbrugden zomertortels afstanden tot 5 km voor voedsel.

Territoria (Hoofdstuk 4.2)

Van de vierdrie volwassen tortels werden vier territoria geïdentificeerd, in grootte variërend van 3 tot 11 ha. Alle territoria waren gelokaliseerd in kleinschalige landschappen, gedomineerd door extensief beheerde graslanden en veel oudere doorgegroeide hagen, bosschages, hogere bomen en poelen. Bram kon één heel broedseizoen lang gevolgd worden. Hij had een territorium van 7,8 ha, waarbinnen meer dan 1 km aan overgroeide/doorgegroeide hagen, struweel en bomen voorkwamen. Grasland omgeven door struweel, hagen en bomen kwam vaker voor in zomertortel territoria dan verwacht kon worden op basis van de aanwezigheid van deze habitats in de gehele 'home range'. Ze laten hier dus een duidelijke voorkeur voor zien. Of die territorium locatiekeuze gebaseerd is op de kwaliteit van het grasland, de aanwezige landschapselementen of een combinatie van beide, kan uit dit onderzoek niet opgemaakt worden. De graslanden werden voornamelijk extensief of voor natuurdoelen beheerd, zowel privaat als door natuurbeheerders zoals Natuurmonumenten. Kleine delen bestonden uit door schapen en paarden begraasde weiden. De meeste zomertortel-activiteit vond plaats in de nabijheid van gemengde hagen en struweel met hogere bomen.



Henk's territory: The highest concentrations of activity were around overgrown mixed-species hedgerow and scrub

Nesthabitat (Hoofdstuk 4.2)

In 2020 werden twee nesten gelokaliseerd van dezelfde zomertortel, Bram. Beide nesten bevonden zich in een dichte meidoornstruik omsloten door ander struweel op een dijktalud. Dunn (2016) signaleerde dat pas uitgevlogen tortels zich meer dan de helft van de tijd ophouden binnen 20 m vanaf de nestplaats. Binnen 20 m vanaf Brams nest was een grote diversiteit aan habitats aanwezig, zoals een grindpad met een brede kruidenrijke berm (deels gemaaid, deels ongemaaid) dat vermoedelijk een toegankelijk en zadenrijk foerageerhabitat vormde. Aanwezige soorten waren onder andere hopklaver, veldlathyrus, vogelwikke en witte klaver.

Nest sites: Bram's nests were located in overgrown scrub, and surrounded by a variety of different habitats

Foerageer locaties (Hoofdstuk 5)

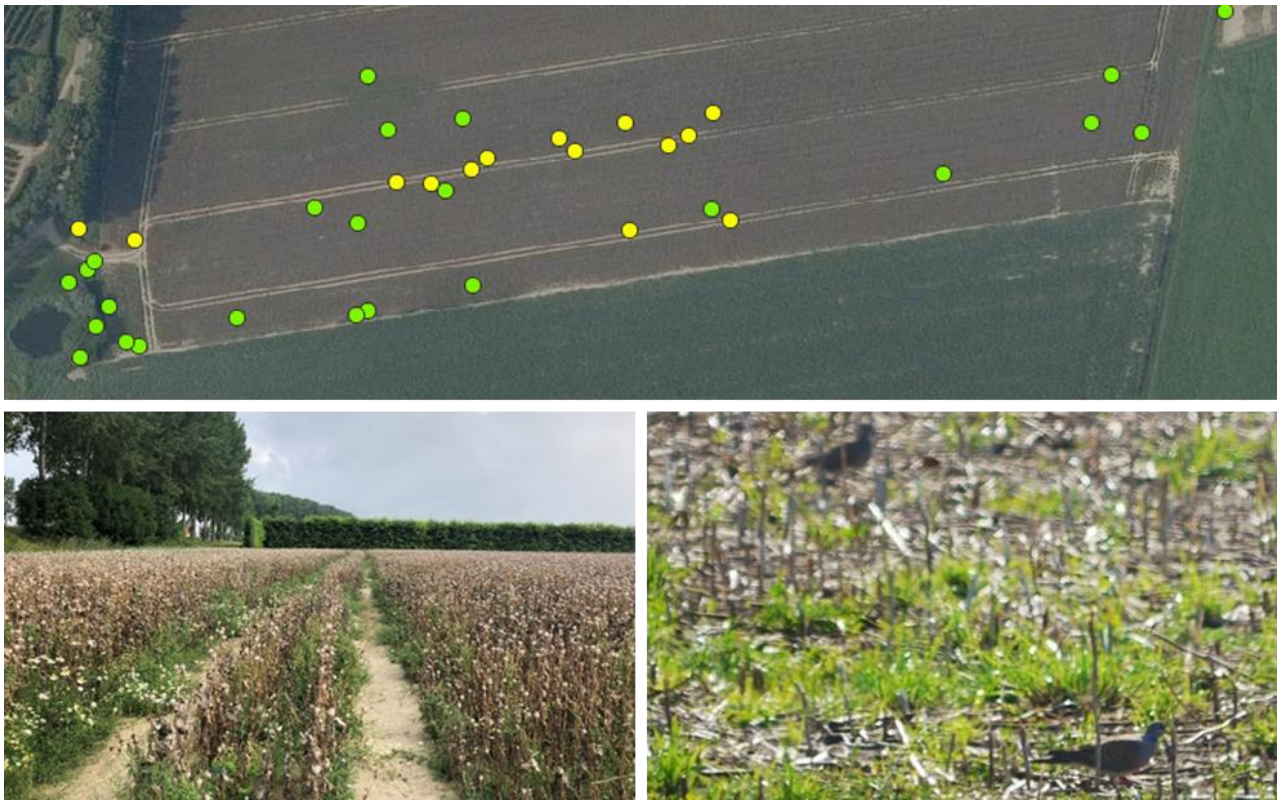
In totaal zijn er 48 foerageerlocaties geïdentificeerd. De helft bestond uit een combinatie van verschillende vormen van landgebruik. Akkerbouwgewassen, grasland, wegen en paden waren vaak aanwezig (Hoofdstuk 5.2). Alhoewel erven bezocht werden, werden geen foerageerplekken gelokaliseerd in steden of dorpen. Hierin onderscheidden de gezenderde zomertortels zich van de algemene en succesvolle Turkse tortel (*Streptopelia decaocto*). Er werden ook geen foerageerlocaties gevonden in de aanwezige akkerranden, dit ondanks de aanwezigheid hiervan gedurende het broedseizoen in de nabijheid van de vastgestelde territoria. Dit vormt een sterke aanwijzing dat de bestaande akkerranden ongeschikt zijn als foerageerhabitat voor zomertortels. Waarschijnlijk komt dit doordat de in de akkerranden aanwezige vegetatie voor zomertortels te hoog en te dicht is. (Hoofdstuk 5.8).

De overige 25 foerageerlocaties werden gedomineerd (>75%) door één vorm van landgebruik. De meest interessante observaties en trends bleken uit de nadere bestudering van de gekozen foerageerlocaties in de loop van de tijd en de onderlinge vergelijking daarvan op een site-by-site basis. In hoofdstuk 5 van dit rapport wordt in meer detail naar de afzonderlijke foerageerlocaties en de bijbehorende landgebruiksvormen gekeken.

Zomertortel activiteit binnen de foerageerlocaties was geconcentreerd aan de randen van akkers, weg(bermen) en grasstroken. In vergelijking met het beteelde landbouwareaal werden al deze locaties gekenmerkt door korte en open vegetaties met een hoge beschikbaarheid aan laag groeiende onkruiden. Vaak waren deze locaties direct in de buurt van opgaande begroeiing, zoals bosschages, hagen en bomen. Een aantal foerageerlocaties week hier sterk van af. Dit betrof een graszaadbedrijf, 4 boerenerven en 6 gewaspercelen. Deze afwijkende locaties kunnen grofweg in twee categorieën onderverdeeld worden: locaties waar zaden beschikbaar waren door menselijke activiteit (voerkuilen en -opslag) en specifieke gewaspercelen die rijk waren aan zaden via het geteelde gewas en/of als gevolg van de aanwezigheid van onkruiden in het gewas.

Op locaties die betrekking hadden op erven van veehouderijbedrijven was de activiteit sterk geconcentreerd rondom voerkuilen, mesthopen en de ruimtes tussen boerderijgebouwen. In 2019 werden zomertortels geobserveerd terwijl ze foerageerden in een voerkuil. Wanneer ze verstoord werden, vlogen ze op naar bomen op het erf. Alle betreffende veehouderijen hadden gehakselde mais in de voerkuil. Waarschijnlijk werden gebroken maiskorrels gegeten. Andere erven die in trek waren hadden allemaal duidelijk wat minder intensief onderhouden rommelhoekjes of paden. Minder intensieve onkruidbestrijding op het erf resulteerde in een hogere beschikbaarheid van zaden.

Over het algemeen werden voornamelijk de randen van akkers en andere landschapselementen gebruikt, maar bij 6 locaties werd het hele perceel gebruikt. Bij die laatste betrof het steeds een gewas met veel openheid zoals zwarte bessen of percelen die in trek waren tijdens en na de oogst van het gewas (tarwe en blauwmaanzaad). In het perceel met zwarte bes werden tussen de rijen geen of weinig herbiciden toegepast, waardoor hier een lage kruidenrijke vegetatie aanwezig was, deels met open grond. Stoppels van geoogste tarwe en blauwmaanzaad hebben eveneens een open vegetatiestructuur en hoge zaadbeschikbaarheid via ongeoogste graankorrels en blauwmaanzaad dan wel via aanwezige onkruiden in de stoppel. De gemene deler van al deze locaties is de open structuur, de hoge zaadbeschikbaarheid en de aanwezigheid van kale grond (Hoofdstuk 5.6).



Turtle doves prefer low, open, seed rich vegetation. Bottom left: before harvest, Henk used machinery tracks to forage in a poppyseed field (GPS locations in yellow). Bottom right: After harvest, he foraged among the stubble over the whole field (GPS locations in green).

Veranderingen gedurende het broedseizoen (Hoofdstuk 6)

Door zomertortels gekozen foerageerlocaties veranderden in de loop van het broedseizoen. Over het algemeen werden erven in het begin van het seizoen bezocht, in de maanden mei en juni. Geleidelijk verschoof het zwaartepunt van de foerageerlocaties daarna meer naar plekken met een gemengd landgebruik, met name naar randen van akkers en bermen langs paden en wegen. In juli werden deze plekken weer ingeruild voor akkerbouwgewassen waar veel open grond en relatief veel onkruiden beschikbaar waren. Na de oogst, richten de gezenderde tortels zich op stoppels van tarwe en blauwmaanzaad.

Ondanks de kleine steekproef van vijf gezenderde zomertortels en twee broedseizoenen, is de veranderende voedsel strategie door het broedseizoen heen indicatief voor aan aantal bredere conclusies.

Zomertortels worden sterk beïnvloed door menselijke activiteit gedurende het broedseizoen

Of dat het nu via erven kort na terugkeer uit Afrika is dan wel aan het einde van het broedseizoen op stoppels van geoogste akkers, zomertortels in landbouwgebieden worden sterk beïnvloed door menselijke activiteit. Op de erven maken ze gebruik van open voerkuilen, gevallen graan en rommelhoekjes. De beschikbaarheid en geschiktheid van dit soort foerageerlocaties zal van jaar op jaar sterk variëren (Hoofdstuk 5.3). In gewaspercelen maakten ze gebruik van spuitsporen om in oogstrijpe gewassen, die zelf te dicht staan, te foerageren. Na de oogst zijn ze afhankelijk van de periode waarin stoppels beschikbaar zijn en niet ondergewerkt worden (Hoofdstuk 5.6). Al deze factoren zijn afhankelijk van keuzes die grondeigenaren keer op keer maken, en die ook resulteren in het wel of niet beschikbaar zijn van voedsel op het juiste moment. Gewaskeuzes en teeltmethoden kunnen dus serieuze consequenties hebben voor zomertortels.

Gebruik van erven is waarschijnlijk uit noodzaak

De resultaten lijken erop te wijzen dat zomertortels een voorkeur hebben voor meer 'natuurlijke' foerageerlocaties boven plekken met veel menselijke verstoring. Alhoewel dit niet gekwantificeerd is, zal er waarschijnlijk gedurende het hele seizoen voldoende voedsel op de bezochte boerderijerven aanwezig zijn. Desondanks verplaatsten de zomertortel hun foerageerlocaties gedurende het seizoen van erven naar meer afgelegen locaties, waarschijnlijk vanaf het moment dat hier voldoende grassen en kruiden zaden produceren. De tortels bezoeken dan uiteenlopende locaties, maar nagenoeg altijd geconcentreerd langs randen van percelen en paden/wegen, locaties waar relatief de meeste onkruiden aanwezig zijn en de vegetatiestructuur open is.

Stoppels behoren tot de meest aantrekkelijke foerageerhabitat

Tijdens het onderzoek is geconstateerd dat zomertortels dagenlang enkele specifieke akkers met geoogste tarwe en blauwmaanzaad opzochten. Er leek in deze periode geen noodzaak te bestaan om naar andere voedselbronnen te zoeken. De intensiteit waarmee de gezenderde tortels de betreffende gewasstoppels bezochten is indicatief voor het hoge voedselaanbod dat deze stoppels na de oogst boden. Alhoewel onduidelijk is of de tortels aten van ongeoogste graankorrels of blauwmaanzaad dan wel van zaden van onkruiden die in het gewas groeiden, in beide gevallen trokken deze specifieke stoppels de aandacht van meer dan alleen de gezenderde tortels. Op verschillende momenten werden meerdere foeragerende tortels in deze stoppels waargenomen (Paragraaf 5.6 – Blauwmaanzaad).

Een gedetailleerde analyse van de foerageerlocaties laat zien dat de gezenderde tortels in het algemeen een voorkeur hebben voor gebieden met veel landschapselementen, zoals bosschages, volgroeide hagen en hogere bomen, in combinatie met de aanwezigheid van verschillende andere elementen zoals randen van akkers, bermen, wegen en paden. Deze combinatie van een kleinschalig landschap met afwisselend gebruik heeft de voorkeur van Zomertortels - een landschap dat voor de verkaveling en intensivering veel gebruikelijker was.

Bram's first nest: Turtle dove Bram, clearly unfazed by his GPS tag, had 2 nests in 2020 and successfully raised a total of 3 chicks

Aanbevelingen (Nederlands)

Aan de hand van dit onderzoek kunnen een aantal conclusies worden getrokken over de habitatvoorkeuren en het gebruik van het landschap door Zomertortels in hun broedgebieden. Alhoewel de steekproef met 5 tortels klein is, zijn deze sterk in lijn met algemenere conclusies die in de literatuur gevonden kunnen worden. Op basis van dit en ander internationaal onderzoek, kunnen een aantal aanbevelingen worden gedaan aangaande het beter beschermen van zomertortels in hun Nederlandse broedgebieden.

De locaties van zomertortelterritoria, in combinatie met de uiteenlopende landgebruiksvormen van de geïdentificeerde foerageerlocaties, wijst erop dat kleinschalige agrarische landschappen met veel landschapselementen voor zomertortels waardevol zijn. Deze landschappen voorzien in een variatie aan verschillende foerageermogelijkheden op een relatief kleine oppervlakte. Met kleinere percelen is er relatief meer randlengte, paden en diversiteit, waardoor de kans op stukken met relatief veel kruidenzaden hoger is. Kleinschalige landschappen herbergen ook meer landschapselementen zoals bomen, struweel en hagen om in te nestelen, en ondiep water om te drinken. De zomertortels vestigden hun territoria gericht in half-natuurlijk terrein, vaak omgeven door extensief grasland. Het is onduidelijk of er een direct verband is tussen dit extensieve grasland en de vestiging van territoria door tortels. (De aanwezigheid van extensieve grasland gaat vaak óók samen met de aanwezigheid van geschikt nesthabitat, waardoor het lijkt alsof de tortels een voorkeur hebben voor grasland.)

Kleinschalige agrarische landschappen zijn in de afgelopen decennia veranderd in grootschalige landschappen, geschikt voor intensieve landbouw. Hierdoor zijn landschapselementen, kleinschalige diversiteit en extensievere randen en hoekjes verdwenen. Dit heeft geleid tot een vermindering van nestgelegenheid en voedselbeschikbaarheid. Om weer de juiste voorwaarden voor zomertortels te realiseren, zal er meer moeten gebeuren dan maatregelen op een enkel bedrijf of perceel. Het realiseren van een geschikt habitat of landschap zal op gebiedsniveau plaats moeten vinden om een gezonde populatie te voorzien van geschikt nesthabitat en voedsel gedurende hun verblijf in Nederland.

De hiernavolgende suggesties voor maatregelen zijn daarom toepasbaar voor gebieden die landschappelijk nog redelijk geschikt zijn, en waar nog een relict populatie aanwezig is. Door het toepassen van deze maatregelen kan dan gepoogd worden de lokale populatie aantallen te stabiliseren en hopelijk weer toe te laten nemen. Een vergelijkbare benadering wordt momenteel ook toegepast in het kader van Operation Turtle Dove in Engeland. Hier wordt gebruik gemaakt van 'Turtle Dove Friendly Zones' om deze gebiedsgerichte aanpak een naam te geven. Enkele van de hier gegeven aanbevelingen worden al aanbevolen richting landeigenaren in Engeland.

ZOMERTORTEL VRIENDELIJKE LANDSCHAPSELEMENTEN

Waar: Agrarische gebieden waar nu nog zomertortels voorkomen, vooral indien bestaand uit grasland of in de nabijheid van grasland

Wie: Alle landeigenaren, agrariërs, maneges, campings, natuurorganisaties etc.

#1. Extra beplanting en goed (=weinig) beheer van hagen en struweel

Goede doorgegroeide hagen en struweel (>3meter hoog) met soorten als meidoorn en sleedoorn kunnen voorzien in nestgelegenheid.

#2. Aanwezigheid van grotere bomen.

Grotere (dode) bomen met een open kroon worden veel gebruikt door zomertortels. In hun territorium wordt veel tijd doorgebracht in deze bomen voor zingen, slapen en aangenaam verpozen. Ook op foerageerlocaties buiten het territorium werden grotere bomen gebruikt in het geval van verstoring. Voorbeelden van geschikte boomsoorten zijn plataan, walnoot, wilg en populier.

#3. Poelen creëren en beheer.
Poelen en vijvers voorzien in drinkgelegenheid. Om geschikt te zijn, hebben deze poelen een flauwe helling zonder hoge begroeiing. In alle vier territoria kwamen deze voor.

ZOMERTORTEL VRIENDELIJK BOEREN
Waar: Alle agrarische bedrijven en land, in het bijzonder in gebieden waar landschapselementen aanwezig zijn
Wie: agrariërs en landeigenaren

#4. Rommelhoekjes.
Boerenbedrijven en erven die door Zomertortels werden bezocht, waren niet de netste aangeharkte en onkruidvrije erven. Het betrof erven met open voersilo's, gemorst voer, oppervlakkig water, kale stukken, open mestopslagen en onkruidrijke plekken en overhoekjes. Het laten verrommelen van overhoekjes of andere plaatsen kan over het algemeen een positief effect hebben op de biodiversiteit. Zeker in het vroege voorjaar is dit voor zomertortels heel waardevol.

#5. Laat je stoppel nog even staan.
Het laten staan van stoppels na de oogst van granen en blauwmaanzaad voorziet in een belangrijke voedselbron in de periode dat jonge tortels opgroeien en de populatie aansterkt voor de terugreis naar Afrika. Met juvenielen die in 2020 pas in augustus uitvlogen en het vertrek naar de overwinteringsgebieden in september is het advies om stoppels tot begin oktober onbewerkt te laten.

#6. Beperk herbiciden gebruik zoveel mogelijk.
In tegenstelling tot veel andere vogels zijn zomertortels in de broedperiode niet afhankelijk van insecten maar van zaden. Alle plekken waar het herbicidegebruik beperkt kan worden en ruimte kan worden geboden aan kruiden zijn daarmee uiterst waardevol.

Photos (clockwise from top left): turtle doves foraging in the large, open poultry run of a small holding; wheat stubble in September; a particularly 'wild' corner of a farmyard (note the silage maize, old hay, overgrown scrub, bare ground and herb-rich

VOEDSELAANBOD VERHOGEN

Waar: Locaties binnen enkele kilometers afstand van territoria

Wie: Vrijwilligers, lokale gemeenschappen, vogelwerkgroepen, landeigenaren en agrariërs

#7. Doe mee met het nood bijvoerprogramma van Vogelbescherming Nederland.

Relatief kleine gebieden waar voer regelmatig, verspreid wordt uitgestrooid, kunnen een belangrijke en betrouwbare voedselbron voor zomertortels zijn. Dit is een noodmaatregel die opgezet is in een poging om een sterk afnemende vogelsoort van voldoende voedsel te voorzien, totdat de lange termijn maatregelen gerealiseerd zijn en ons landschap weer geschikt is voor deze vogels. Noodvoerplekken worden ingezet door Operation Turtle Dove (Engeland) en Operatie Zomertortel in Nederland.

#8. Realiseer geschikte voedselvelden.

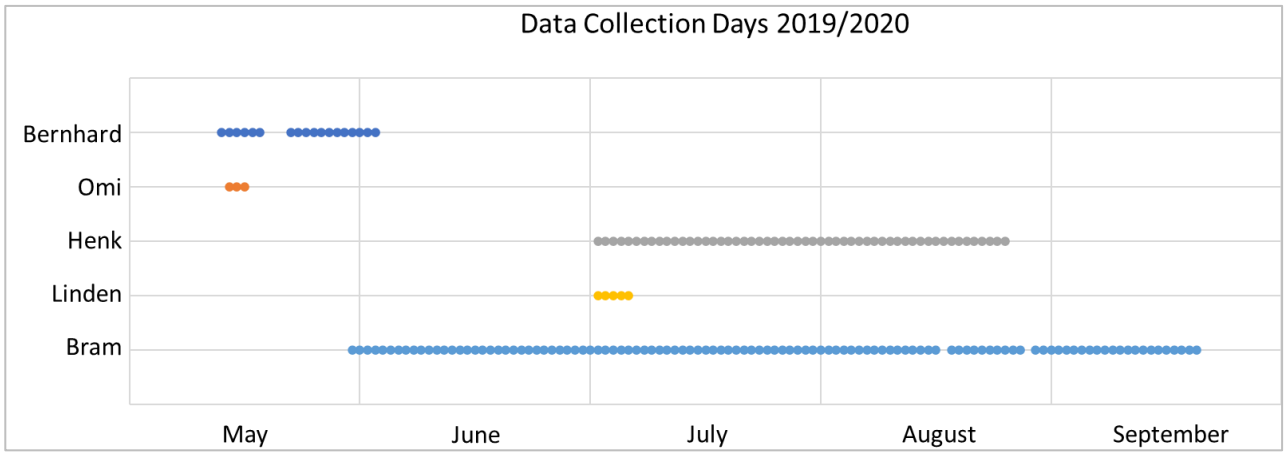
Het ontwikkelen en realiseren van voedselveldjes in de nabijheid van zomertortel territoria kan de soort helpen. Deze veldjes dienen een lage vegetatie-dichtheid en een open structuur te hebben. De vegetatiehoogte dient ca. 20 cm te zijn met een percentage van 30-60% kale grond. Voedselveldjes moeten een verschillende zaden producerende gewassen en onkruiden bevatten, zodanig dat het vanaf het vroege in voorjaar tot eind september voedsel levert (zie onderstaande voorbeelden van geschikte soorten). Belangrijke overweging hierbij is dat gebrek aan zaden zich waarschijnlijk het sterkst doet gelden op het moment van hun terugkeer uit Afrika in april/mei. Het realiseren van voedselveldjes zou de populatie minder afhankelijkheid kunnen maken van het artificiële bijvoerprogramma en toevalligerwijs aanwezige geschikte boerenerven en stoppels van geoogste gewassen. De meest recente inschatting van de RSPB is dat 2-4 ha voedselveldje per 100 ha voldoende zouden kunnen zijn.

Engels	Latijns	Nederlands
Herbs		**Kruiden**
Common fumitory	*Fumaria officinalis*	Gewone duivenkervel
Common chickweed	*Stellaria media*	Vogelmuur
Redshank	*Polygonum persicaria*	Perzikkruid
Mayweed	*Tripleurospermum sp.*	Reukloze kamille
Clovers	*Trifolium sp.*	Klavers
Buttercups	*Ranunculus sp.*	Boterbloemen
Black medick	*Medicago lupulina*	Hopklaver
Common poppy	*Papaver rhoeas*	Grote klaproos
Common vetch	*Vicia sativa*	Voederwikke
Vetch species	*Lathyrus sp.*	Lathyrus soorten
Grasses		**Grassen**
Meadow grass species	*Poa sp.*	Beemdgras soorten
Bent grass species	*Agrostis sp.*	Struisgras soorten
Vernal grasses	*Anthoxanthum sp.*	Reukgras soorten
Red fescue	*Festuca rubra*	Roodzwenkgras
Crop Species		**Gewassen soorten**
Radish	*Raphanus sp.*	Radijs
Oil-seed rape	*Brassica napus*	Koolzaad
White and yellow mustard	*Sinapis alba*	Witte/gele mosterd

Abstract

In the past decades, the European turtle dove (*Streptopelia turtur*) has been suffering a massive population decline across its whole range. In the Netherlands, the breeding population has plummeted by 97% since the 1980s and there are now less than 1200-1400 pairs remaining (Sovon 2013/2015 survey). The European Commission and its partners released an International Species Action plan for this 'vulnerable' Red List species, detailing the issues and identifying knowledge gaps across the turtle doves' range. One of these gaps is our knowledge about their small-scale movements within their breeding areas.

This research was set up to gain insight into the daily movements of turtle doves in the Zak van Zuid-Beveland (Zeeland, the Netherlands). This report is an analysis of data collected in 2019 and 2020. The study has focussed on investigating the home ranges and territories of the doves, and identifying their land use preferences for foraging. Five male turtle doves, one of which was a recently fledged young, were equipped with GPS telemetry loggers which recorded their location at fixed intervals. A total of 2450 locations were recorded in the 2019 and 2020 breeding seasons.



GPS-Data collection: five turtle doves were followed using GPS-transmitters, each for a different period of time

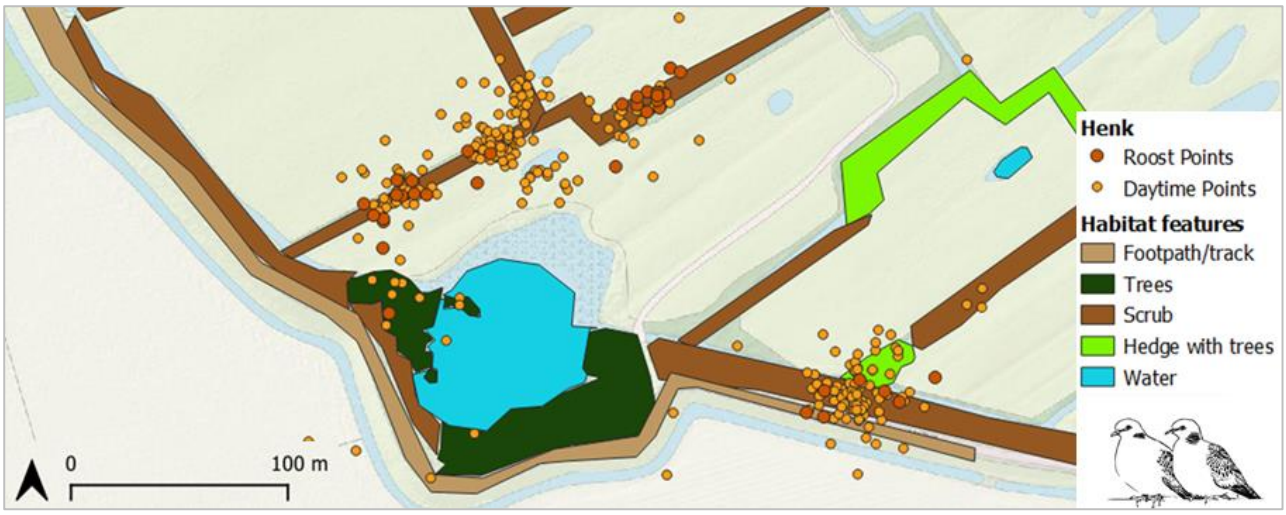
The analysis of this data provided an insight into how the turtle doves were using the landscape on a daily basis. This report discusses the 'home ranges', territories, nesting habitat and foraging sites of these five turtle doves.

Home Range (Chapter 4, Section 1)

Home ranges varied from 3.9 (the young dove) to 1300 ha and the doves flew up to 5 km to forage.

Territory (Chapter 4, Section 2)

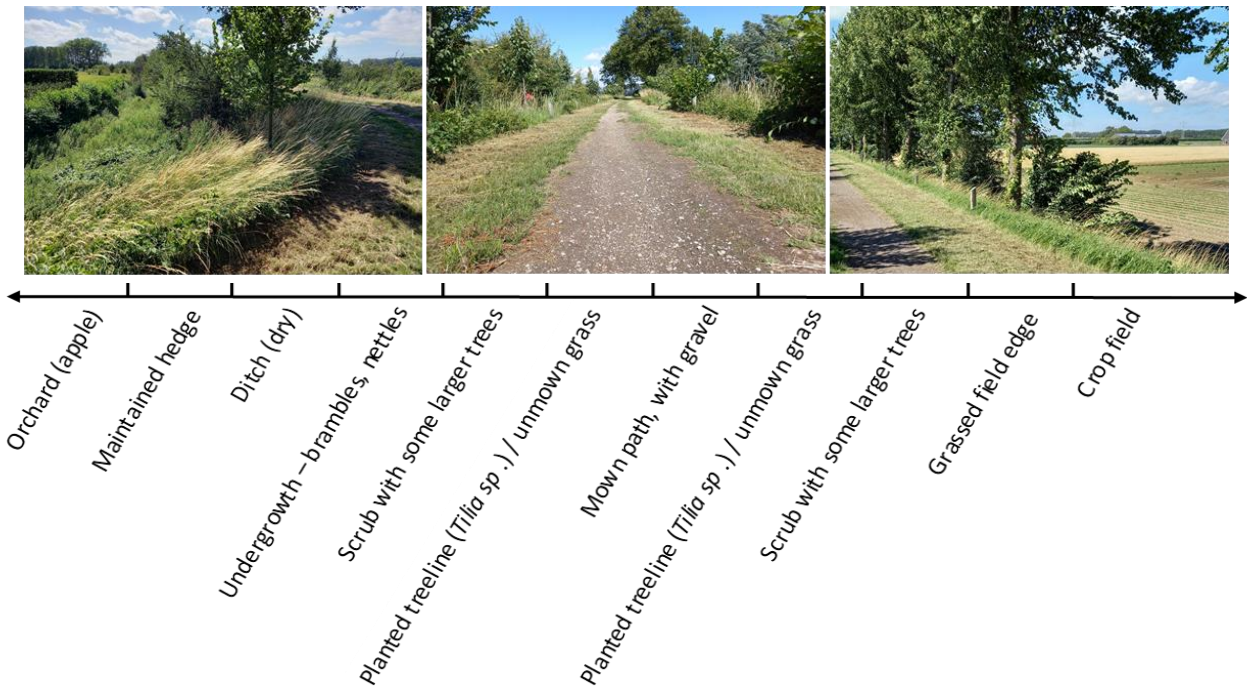
Four territories were identified for the breeding male doves, ranging from 3 to 11 ha. They were found to be strategically located in small scale agricultural landscapes, dominated by extensive grassland and containing a significant number of overgrown hedgerows, areas of scrub, taller trees and permanent ponds. For example, Bram, who was followed through a whole breeding season, had a territory of 7.8 ha that contained more than 1 km of overgrown scrub/hedge/trees. Grassland habitat with plenty of scrub/trees featured more prominently in turtle dove territories compared to its availability within their home ranges. Whether the grassland, the landscape features, or a combination of the two, led to territories being established here is unclear, but territory locations were not being selected at random. The grassland itself was predominantly managed for nature – either privately owned or owned by nature organisation Natuurmonumenten. Small portions of their territories were grazed by horses or sheep, or were managed as small crop fields by Natuurmonumenten. The highest concentrations of turtle dove activity were found around overgrown mixed-species hedgerow and scrub with taller trees growing through them.



Henk's territory: The highest concentrations of activity were around overgrown mixed-species hedgerow and scrub

Nesting Habitat (Chapter 4, Section 2)

There were 2 nests found in 2020, both from Bram. These were found in hawthorn trees located in stands of scrub along a dike. Dunn (2016) found that newly fledged doves spend more than half their time within 20 m of their nest, with almost all (95%) foraging trips being within a 329 m radius. Within a 20 m radius of Bram's nest site a variety of habitats was represented – for Bram, the most interesting of these were likely a bare gravel/sand footpath and wide borders of unmown and mown herb-rich grassland, which would have provided suitable seed-rich foraging habitat. Species represented here included black medick, bird vetch, meadow vetchling and white clover. The variety of different habitats surrounding the nests is typically representative of small-scale landscapes.



Nest sites: Bram's nests were located in overgrown scrub, and surrounded by a variety of different habitats

Foraging Sites (Chapter 5)

A total of 48 foraging sites were identified, half of which contained a mixture of different land uses (Section 5.2). Here, crop, grassland and road/track predominated. No foraging sites were located in towns or villages, suggesting that the tagged turtle doves were not accustomed to visiting gardens alongside their more common relative, the collared dove. There were also no foraging sites recorded at existing agri-environment field margins, despite them being available in the immediate vicinity of dove territories. This is a strong indicator of their unsuitability as turtle dove foraging habitat, most likely due to the height and density of the vegetation structure (Section 5.8).

The remaining 25 foraging sites contained more than 75% of a single land use. However, the most interesting observations and trends only emerged once the distribution of turtle dove datapoints was considered and compared on a site-by-site basis over time. Chapter 5 of this analysis considers a range of individual sites in greater detail, representing a variety of land uses.

Turtle dove activity within the majority of foraging sites was concentrated around field borders, grassy verges, roads and tracks. These areas had sparse vegetation, plenty of bare ground, and a heightened quantity of low-growing weeds compared to the cultivated areas. In addition, they were often close to trees, scrub or hedges. There were several sites where the turtle dove's foraging behaviour differed. This included a grass seed factory, 4 farms, and 6 crop fields. These sites could be loosely classed into two categories: sites where seed was made available through humans (silage/storage), and certain crop fields that were particularly seed-rich (crop and/or weed seed).

At sites such as dairy farms, activity was most concentrated around silage heaps, manure piles and farmyard in between buildings. In 2019, turtle doves were observed foraging in the silage channel and flying to a nearby cluster of trees when disturbed. All dairy farm foraging sites were using silage maize, which likely contained broken corn for the doves to forage on. Other farmyards contained visibly 'wild' and weed-rich corners and tracks: less weed control on the farmyard means more weeds, which in turn provides greater seed availability.

In general, field edges and landscape elements were used at foraging sites, but at 6 sites the doves showed interest in the crop itself. Here, their activity was spread across the whole site. Of these 6 sites, the crops were *either* minority crops containing a lot of bare ground (such as blackcurrant), *or* they were seed/grain fields visited around harvesttime (such as wheat and poppyseed). In the blackcurrant field, paths between the rows of bushes were unsprayed, weed-rich and had a low, sparse vegetation structure. A harvested wheat field also had the low, open vegetation structure preferred by turtle doves, and was rich in fallen grain. The core similarity found between these crop foraging sites was the open structure of the vegetation and the high proportion of bare ground (Section 5.6).

Turtle doves prefer low, open, seed rich vegetation. Photo bottom left: before harvest, Henk used the machinery tracks to forage in this poppyseed field (GPS locations in yellow). Photo bottom right: After harvest, he foraged among the stubble over the whole field (GPS locations in green).

Preferred Foraging Land Use: change over time (Chapter 6)

Foraging site land use and site utilisation by doves were found to change over the course of the breeding season. On the whole, farmyards were frequented earlier in the season, in May and June. These were supplemented and then gradually replaced by foraging sites characterised by a mixed land use composition, where foraging around the field margins and tracks became more pronounced. In July these sites were gradually replaced by crop dominated sites, containing a lot of bare ground and relatively many weeds. Once harvest arrived in the Zak van Zuid-Beveland, the tagged doves were recorded using the stubble of wheat and poppyseed fields the most intensely.

Despite the small sample size, the shift in land use composition and how the sites were utilised is indicative of several broader conclusions.

Turtle doves are heavily impacted by human activity

Whether earlier in the breeding season on farmyards, or later in the breeding season at harvested grain/seed fields, turtle doves in agricultural areas are heavily impacted by human activity. At farmyards, they depend on open silage channels of silage maize, spilt grain and wild corners, which vary in their location and availability annually (Section 5.3). At harvested fields, doves were observed using the tracks of farm machinery to forage around ripe grain/seed crops. After harvest, they are dependent on each landowner's decision to leave crop stubble several days/weeks before ploughing (Section 5.6). All these factors are the result of land owner decisions and result in an unreliable source of food each year. A single year where few grain/seed fields are planted, or where few fields are left as stubble, could have serious consequences for local turtle doves – particularly those with a late nest of chicks to support.

Turtle doves forage at farmyards out of necessity

Turtle doves appear to prefer more 'natural' foraging sites to sites with a lot of human disturbance. Although difficult to quantify, sufficient food for turtle doves is likely to be available at farms for most of the breeding season. However, the tagged doves shifted away from farmyards to more remote sites from early to mid-June – coinciding with the first 'weed' and grass species setting seed (Chapter 6). The doves frequented a range of sites, concentrating their activities on field margins and tracks - areas most likely to have been missed by sprayers and therefore supporting a greater abundance of weeds.

Harvested crop fields provide some of the most attractive foraging habitat

Turtle doves were seen to visit a single harvested wheat or poppyseed field for days on end, apparently never needing to look for food elsewhere. The intensity to which tagged doves used these sites is indicative of their high foraging value. While it's unclear whether the doves were foraging on spilt seed or on weeds that had grown up under the crop, in both cases the fields attracted the attention of more than just the tagged doves. On numerous occasions additional turtle doves were seen foraging at these sites (Section 5.6 – Blue Poppyseed).

A detailed look at the foraging sites frequented in this study revealed that the tagged turtle doves had a general preference for areas containing many landscape elements, such as scrub, overgrown hedges and taller trees. They also preferred areas with a variety of different land uses, such as grassy roadside verges, field borders, roads and tracks. This combination is reminiscent of the small-scale landscape known to be preferred by turtle doves – a landscape that was far more commonplace before the intensification of farming.

Bram's first nest: Turtle dove Bram, clearly unfazed by his GPS tag, had 2 nests in 2020 and successfully raised a total of 3 chicks

Recommendations

Based on this research a number of conclusions can be drawn regarding the land use and habitat preferences of turtle doves in their breeding grounds. While the sample size during this study was small, these conclusions appear in line with more generalized conclusions found in literature and international research. On this basis, a number of recommendations can be made regarding what can be done to help turtle doves in their Dutch breeding grounds.

The location of turtle dove territories, combined with the mixed land-use at many foraging sites, indicates that small scale agricultural landscapes are (still) valuable to turtle doves. These landscapes provide a variety of different foraging habitats over a comparatively small area; the smaller field sizes result in relatively more tracks, uncultivated field margins, and limited weed control, making this landscape rich in weeds. They also contain a wealth of landscape features such as trees, scrub and hedges for nesting, and shallow pools for drinking. In the case of territory location, herb-rich grassland was found to be an important component – doves were strategically establishing their territories in un-cropped habitats, centred around grassland areas. However, whether there is a direct relationship between grassland and territory location was unclear (i.e. grasslands often have more suitable nesting habitat, causing doves to favour grassland).

Small-scale agricultural landscape has been gradually replaced by large-scale fields suitable for intensive agriculture, thereby reducing landscape features and grassland, and limiting foraging and nesting opportunities. Turtle doves therefore require intervention and assistance on a greater scale than a single farm or field. The creation of suitable habitats needs to be applied to larger areas if it is to succeed in attracting and supporting a viable population of territories and foraging sites.

The following recommendations are designed for suitable areas where there is still a (remnant) population of turtle doves, with the aim of stabilising and, eventually, increasing their numbers here. A similar initiative has already been started by Operation Turtle Dove in England, where the phrase 'Turtle Dove Friendly Areas' has been coined. Some of the recommendations contained here are already being advised to land owners in the UK.

Turtle Dove Friendly Landscape Features

Where: Any area containing turtle doves, with particular focus on land in, or close to, grassland
Who: All land owners - farmers, small holdings, riding stables, campsites, nature organisations, provinces etc.

#1. Increase and manage hedge and scrub.

Overgrown (>3m tall) scrub and hedgerow, containing species such as hawthorn and blackthorn, provides suitable nesting habitat.

#2. Presence of taller trees.

Taller (dead) trees with loose and open canopies are used by turtle doves. In their territory, the doves use trees for singing, roosting and loitering. At foraging sites, they are used for shelter when the doves are disturbed. Species such as plane tree, walnut, willow and poplar are all suitable examples.

#3. Creation of permanent pools.

Permanent pools and ponds provide drinking water. Ponds need to have at least 1 gently sloping or shallow area that is reasonably vegetation free and accessible to doves. All four of the territories identified during this research contained at least one permanent pool or pond.

Turtle Dove Friendly Farming
Where: All farms and agricultural land, particularly in areas where there is suitable nearby scrub, hedge or trees
Who: All farmers and landowners

#4. Leave wild corners on your farm.
Farms visited by turtle doves during this research were not the 'tidy' and 'weed free' farms, but those with open silage channels, spilt feed, pools of water, bare ground, open manure heaps and farmyards/tracks that were not treated against weeds. Setting aside small parts of the farm to become more wild and less maintained can have a positive effect on wildlife – not least, on foraging turtle doves earlier in the year.

#5. Leave crop stubble until the end of September.
Leaving the stubble of grain/seed crops, such as poppyseed and wheat, provides valuable foraging habitat for turtle doves in the late summer. With the last chicks fledging in August and doves building up their condition in preparation for migration in September, it's advisable to leave your stubble untouched until the start of October.

#6. Limit spraying to where it is essential.
Contrary to many birds, turtle doves are not reliant on insects but on seed. Any area where spraying can be limited and herbs/weeds are allowed to grow is a great food source for foraging turtle doves, particularly from May until the end of July.

Photos (clockwise from top left): turtle doves foraging in the large, open poultry run of a small holding; wheat stubble in September; a particularly 'wild' corner of a farmyard (note the silage maize, old hay, overgrown scrub, bare ground and herb-rich

Providing Suitable Foraging Areas
Where: Any area within a few kilometres of breeding turtle doves
Who: Volunteers, local communities, local bird groups, landowners and farmers

#7. Join the Emergency Feeding Scheme initiative from Vogelbescherming Nederland.
Small areas where suitable seed is regularly but thinly spread by volunteers can provide a reliable food source throughout the breeding season. This is a short-term, emergency measure that is designed to reduce/halt the further decline of struggling turtle dove populations until more long-term measures are in place. Emergency feeding stations have been taken up by Operation Turtle Dove (England) and Operatie Zomertortel (in the Netherlands).

#8. Create suitable foraging fields.
The development and creation of attractive foraging fields, particularly within 1 km of turtle dove territories, would benefit the species. These fields need to have an open and low-density vegetation structure: plants should be kept lower than 20 cm, and bare ground should comprise 30% - 60% of the total area. Fields should provide a good variety of seed for turtle doves throughout the entire breeding season (example species below), with particular focus on bridging the food shortage they experience upon their return from Africa in May. The provision of foraging fields could reduce the turtle doves' reliance on emergency feeding stations, on farmyards in May and June, and on farming decisions regarding harvest/ploughing later in the season. The most recent guidelines from the RSPB suggest that 2-4 ha of foraging fields per 100 ha could be sufficient.

English	Latin	Dutch
Herbs		Kruiden
Common fumitory	*Fumaria officinalis*	Gewone duivenkervel
Common chickweed	*Stellaria media*	Vogelmuur
Redshank	*Polygonum persicaria*	Perzikkruid
Mayweed	*Tripleurospermum sp.*	Reukloze kamille
Clovers	*Trifolium sp.*	Klavers
Buttercups	*Ranunculus sp.*	Boterbloemen
Black medick	*Medicago lupulina*	Hopklaver
Common poppy	*Papaver rhoeas*	Grote klaproos
Common vetch	*Vicia sativa*	Voederwikke
Vetch species	*Lathyrus sp.*	Lathyrus soorten
Grasses		Grassen
Meadow grass species	*Poa sp.*	Beemdgras soorten
Bent grass species	*Agrostis sp.*	Struisgras soorten
Vernal grasses	*Anthoxanthum sp.*	Reukgras soorten
Red fescue	*Festuca rubra*	Roodzwenkgras
Crop Species		Gewassen soorten
Radish	*Raphanus sp.*	Radijs
Oil-seed rape	*Brassica napus*	Koolzaad
White and yellow mustard	*Sinapis alba*	Witte/gele mosterd

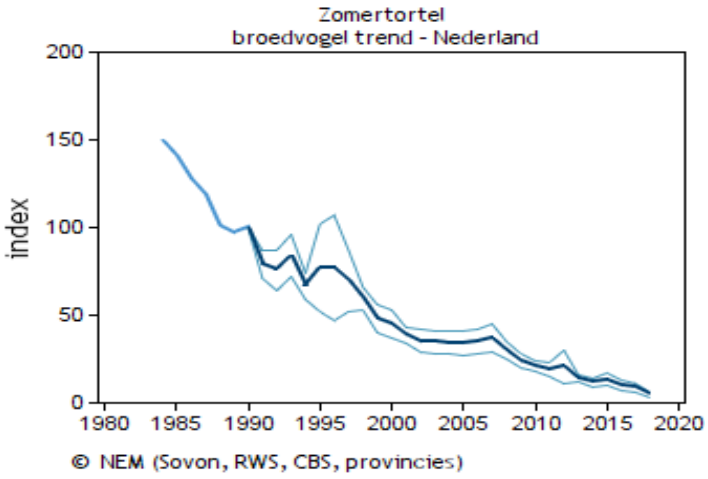
1 Introduction

The turtle dove is a small, strikingly coloured dove that is currently suffering massive population decline across its whole range. In the Netherlands the breeding population has plummeted by a shocking 97% since the 1980s. The turtle dove is now a 'vulnerable' IUCN Red List species with less than 1200-1400 pairs remaining in 2015 (Sovon).

Known factors responsible for their population decline are a complex and international issue. These include:

- Habitat loss across their breeding range
- Habitat loss across their wintering range
- Hunting
- Illegal trapping and killing
- Disease

Limited knowledge about the turtle dove, combined with their population decline, has led to the compilation of an International Species Action Plan by the European Commission and Convention on Migratory Species (completed May 2018). This plan identifies issues and knowledge gaps across the turtle doves' range. It also sets out the next steps countries will need to take in order to halt the decline and ultimately restore the population.



In the Netherlands, the only factor that we can directly influence is breeding range habitat loss. This 2-year project aims to answer some key research questions and communicate our findings to a wider public. In addition, it addresses several objectives and actions set out in the International Single Species Action Plan for the turtle dove (Appendix 1).

Project Focus

The focus of this project is on gaining insight into the daily foraging behaviour and habitat preferences of turtle doves breeding in Zeeland. In addition, data will be gathered during their migration/overwintering period which will be available upon each bird's return to its breeding grounds in the spring.

Research Questions

- What small scale movements do turtle doves make in the breeding season in the Zak van Zuid-Beveland?
- Do the tagged turtle doves have a territory? If so, what habitat is it and what landscape features are present/absent?
- What land use/s do the foraging turtle doves prefer?
- Where is turtle dove activity the most concentrated within foraging sites? And what are the possible reasons for this?
- During the breeding season, are there any trends in foraging site choice over time?
- If nesting locations are identified, what can we say regarding their nesting habitat requirements?
- If nesting locations are identified, how does an active nest impact foraging site choice?

2 Methodology

2.1 Study Area

The chosen study area was the "Zak van Zuid-Beveland", in Zeeland: a rural area of the province, scattered with farms and villages. This area was selected for two main reasons. Firstly, it is known to contain a remnant population of breeding turtle doves. Secondly, this area was selected because of its proximity to field researchers in Goes – all sites were within a 20-minute driving radius, which meant the frequency of site visits and data collection could be maximised. Figures 1 and 2 show the breeding density of turtle doves (as calculated in 2015 by Sovon), and the territories identified in the Zak van Zuid-Beveland in 2019 and 2020. In 2019, there were 8 turtle dove territories within the study area (Marcel Klootwijk, 2019). In 2020, only 4 territories were identified.

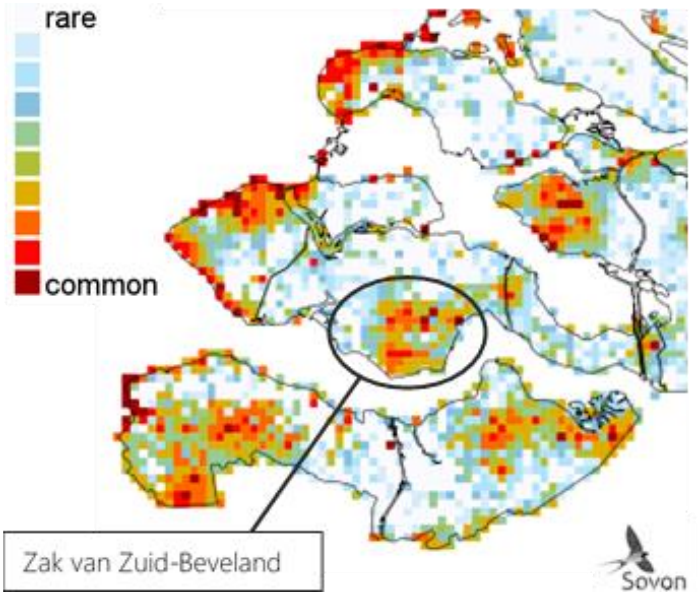


Figure 1 (right): turtle dove breeding density in Zeeland (rare to common), 2013-2015, Sovon Vogelatlas

Figure 2: Territories in the Zak van Zuid-Beveland, 2019 and 2020

2.2 Feeding Stations

In order to capture turtle doves, temporary feeding stations were required as 'bait' to draw doves to an area where a suitable net could be set up. Feeding station sites (Figure 3) were selected and maintained using the protocol of Operation Turtle Dove as a basis: close to water and nesting habitat, with short, patchy vegetation (<15 cm high) and plenty of bare ground (30 - 60%). In contrast to Operation Turtle Dove's protocol, a number of stations were established under tree canopy rather than in the open. Feeding stations measured 2 x 2 m and were set up before the return of doves, so as to attract the interest of other foraging birds. Seed was spread thinly over the whole area and replenished between 2 and 5 times per week, as required. Commercial seed mixes for doves (including turtle doves) were used. Feeding stations were monitored using a combination of field observations and camera traps. Following catching, stations were built off within days so as to minimise their influence on data collection.

Year: 2019

At the end of March 2019, 9 feeding stations were set up, of which 3 were located under tree canopy. Turtle doves were heard from May in the vicinity of 7 of these sites. Observations and camera footage confirmed that turtle doves were frequenting 5 of the stations.

Year: 2020

A total of 7 feeding stations were set up in 2020: 5 of which were from 2019, plus an additional 2 locations. Stations were opened in late April/early May, and the first turtle doves arrived in the Zak van Zuid-Beveland in late May. Singing turtle doves were heard at just 2 of the feeding stations, and none of the sites were confirmed as being used by turtle doves in 2020. Close to one of the stations was a small-holding/sheep farm where doves came to feed in a large, open poultry coop. Ultimately, the only dove tagged in 2020 was captured at this site.

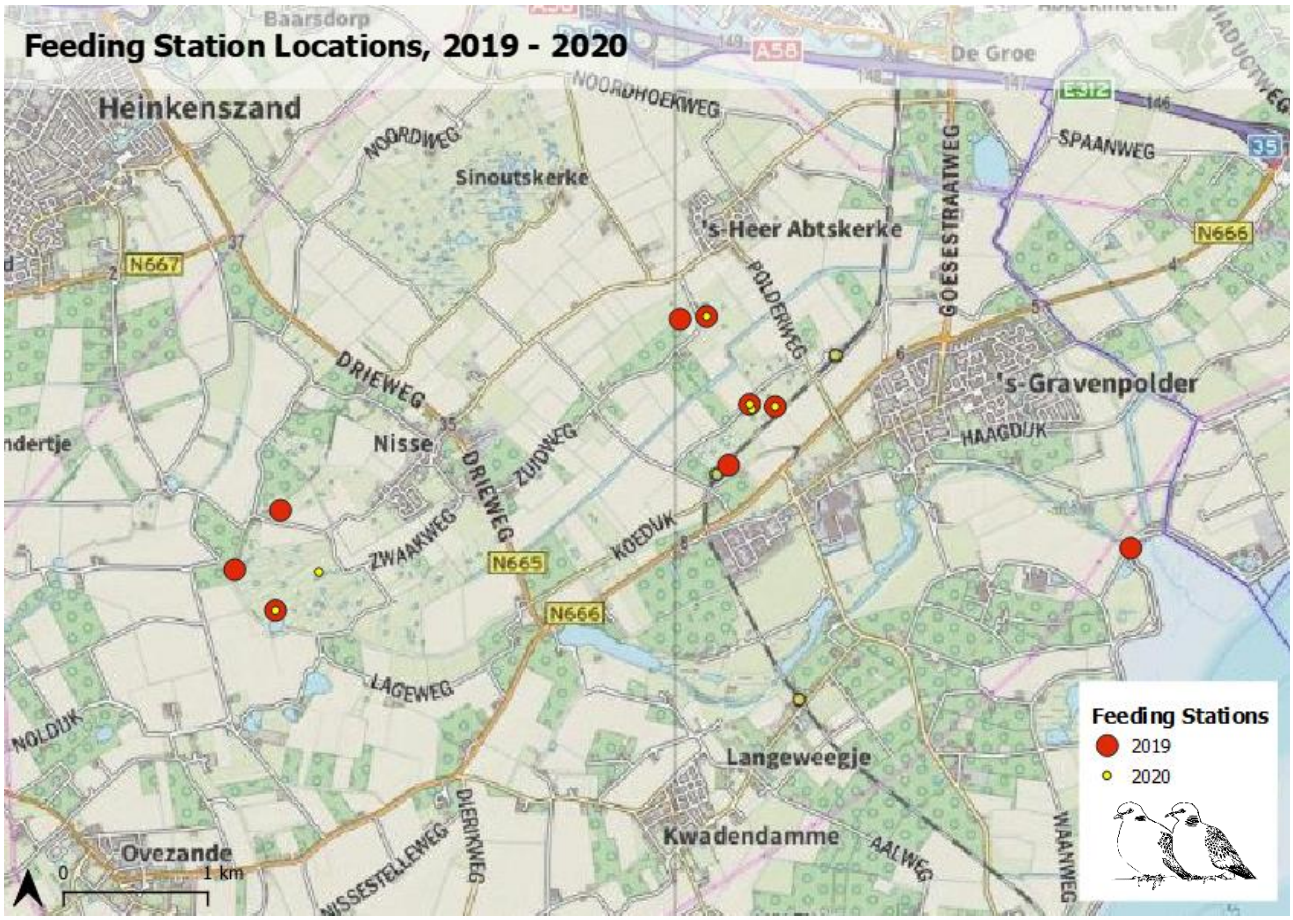


Figure 3: Feeding stations in 2019 and 2020

2.3 Tag and Harness

Milsar's NanoRadioTag-3 telemetry loggers were used in this research. These tags are light weight (3.5 g) and record and store GPS locations at pre-set intervals. They also have the useful added features of a solar powered battery, remotely adjustable tag settings and remote data download. Data is downloaded by means of a base station when a tag is within a certain range. The NanoRadioTag-3 has a range of 2 - 5 km (hilltop to hilltop) but this range is much lower when tags and base station are used in a flat landscape containing features such as trees, buildings of hedges.

Photo: Milsar NanoRadioTag-3

The generally accepted weight of a tag, compared to a bird's body weight, is either 3% or 5%, depending on where you read. Although many studies have been carried out regarding the impacts of transmitters, there was a paucity of data for the European turtle dove. Elsewhere in Europe, turtle dove tracking studies predominantly use 5 g satellite 'PTT' tags. Countries such as Germany (NABU), England (RSPB) and France (La Office National de la Chasse) have been conducting turtle dove research using these tags since 2014. One dove, 'Francesco', tagged by NABU in Malta (April 2017) delivered migration data for more than 3 years.

This study used the more precautionary 3% rule for tag weight, with the combined weight of tag, metal identification ring and harness making up less than 5% of the dove's body weight. The weight range for turtle doves is 85 – 170 g, so there was a risk of capturing a dove and not being able to tag it. Only doves weighing more than 116 g (at time of capture) were tagged, regardless of sex and age.

This study employed a full body harness of 2 mm tubular Teflon tape, known not to cause feather damage, and the harness design is the same as that currently employed in Germany and Malta. Researchers in France and Spain use very similar full-body harnesses of Teflon tape. There have been some concerns in the UK regarding the potential impact of full-body harnesses on the pectoral muscles of doves. While other European countries continue to use full body harnesses, the UK has now stopped. Ultimately, more research is needed into different harness designs and materials, as well as the impact of extra weight on European turtle doves.

2.4 Licencing

Ringing turtle doves with a standard metal ring is licenced by Vogeltrekstation (the Dutch Centre for Avian Migration and Demography). Use of GPS tags on this project is licensed by the University of Groningen, under Article 10a of the Animal Experimentation Act (Wet op de Dierproeven) by the Central Commission for Animal Testing in the Netherlands. Catching, ringing and tagging was carried out by a qualified professional.

2.5 Training

A training day was held at an aviary in Limburg, where turtle dove researcher Yvonne Schumm (Justus Liebig University Giessen, Germany) demonstrated how the turtle dove harnesses and tags should be deployed. The training day was supervised by Dutch qualified bird ringer Raymond Klaassen, who oversees several telemetry projects at the University of Groningen. During training, a harness and dummy tag were tried and tested on aviary turtle doves 2 months in advance of tagging wild turtle doves. The final training turtle dove, an adult male, was released back into his aviary equipped with the dummy tag. He was subsequently observed and displayed no negative physical or behavioural effects from the tag and harness. The tag was removed after 22 months, with the conclusion of this study.


Photos: Aviary turtle dove being equipped with a full body harness and dummy tag, March 2019

2.6 Capture and Tagging

Once a feeding station was visited daily by turtle doves, a 'bownet' was set up and locked open for them to become accustomed to. A few days later, catching was attempted. During this research, 5 turtle doves were caught and equipped with GPS tags. Once released the birds immediately started providing their GPS locations according to a pre-set interval which could be changed remotely. This information was stored on the tag and downloaded periodically using a base station. Table 1 provides an overview of the doves tagged. Gender was determined in the field based on the dove's plumage and eye ring, and was later confirmed using a feather DNA test. Upon completion of this project, the appropriate feeding stations will be maintained and monitored in May and June 2021 for returning doves. Doves that return from their wintering grounds will be captured and assessed: doves in good health, carrying a working transmitter will be followed for an additional breeding season. Doves showing any sign of physical or behavioural difficulty, or whose transmitter has stopped working, will have their tag removed.

Bird #	Dove Name	Tag ID	Ring Number	Date Ringed	Age (years)	Gender	Weight (grams)	%* of Weight
1	Bernhard	998003	2518152	13/5/2019	>1	Male	146.68	2.4%
2	Omi	998002	2518153	14/5/2019	>1	Male	165.00	2.1%
3	Henk	998004	2518154	01/7/2019	>1	Male	166.50	2.1%
4	Linden	998001	2518155	01/7/2019	<1	Male	118.20	3.0%
5	Bram	998004	2518156	30/5/2020	>1	Male	166.4	2.1%

Table 1: General information about each dove – further details in Appendix 2

* 3.5 g tag compared to the bird's body weight

2.7 Tag Accuracy

The Milsar NanoRadioTag-3 specifications state that the tag is accurate to 10 m, but this was tested. Based on a sample of 157 points, the mean coordinates were calculated and the distance measured between this location and each recorded point. The mean distance was 9.2 m, with a standard deviation of 7.7 m.

Assuming a normal distribution of the data, this means that 68% of the collected points fall within 7.7 m of the actual location of the tag, and 95% of points recorded are within 15.4 m of the tag. The furthest point from the actual tag location was recorded 40.8 m away.

With this in mind, this study has taken the accuracy of these tags to be 15 m, which should be true for more than two thirds of all our collected datapoints.

3 Data Overview

During the 2019 and 2020 breeding seasons, 2450 locations were registered and downloaded from the 5 project doves. These points cover the period mid-May to mid-September (Figure 4).

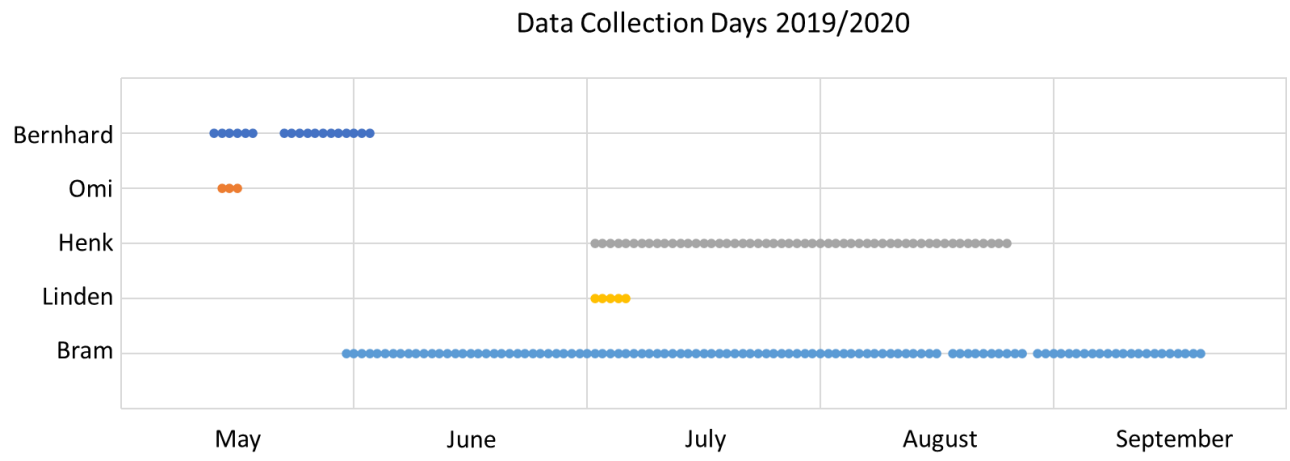


Figure 4: Data collection days visualised per dove

Turtle doves are diurnal and are therefore stationary (roosting) at night, so tags were programmed to record more coordinates during daylight hours, when the birds were active. During the breeding season, hours of darkness were taken to be between 00:00 and 05:00, making the day:night ratio of points collected approximately 12:1. Points recorded during 00:00 and 05:00 are hereafter referred to as "roost points". Table 2 provides an overview of the data collected from each dove. We lost contact with both 'Omi', an adult male, and 'Linden', a 1st year male, within a few days of equipping them with GPS tags. Bernhard, Henk and Bram however, remained in our study area for longer.

Dove Name	Monitoring Period 2019 (DD/MM)	Monitoring Period 2019 (days)	Days with Data	Total points	Points/ Day min	Points/ Day max	Territorial Behaviour seen
Bernhard	13/05 – 08/06	27	18	371	1	73	Yes
Omi	14/05 – 16/05	3	3	142	33	66	Yes
Henk	01/07 – 23/08	54	54	587	4	16	Yes
Linden	01/07 – 05/07	5	5	38	6	10	No
Bram	30/05 – 17/09	111	109	1312	2	53	Yes

Table 2: Overview of the data retrieved from project doves in 2019/2020

Datapoints from the 5 doves cover a large part of the Zak van Zuid-Beveland: from Kapelle in the east to Rijkebuurt in the west, and as far south as Koekoek (Figure 5). The small-holding and 2 feeding stations where all 5 doves were tagged are located in the 3 largest clusters: Omi and Bernhard were captured on Bergweg, Henk and Linden in the Heggengebied, and Bram at the Schaapskooi. These 3 large clusters are also the locations of the 4 turtle dove territories found during this project.

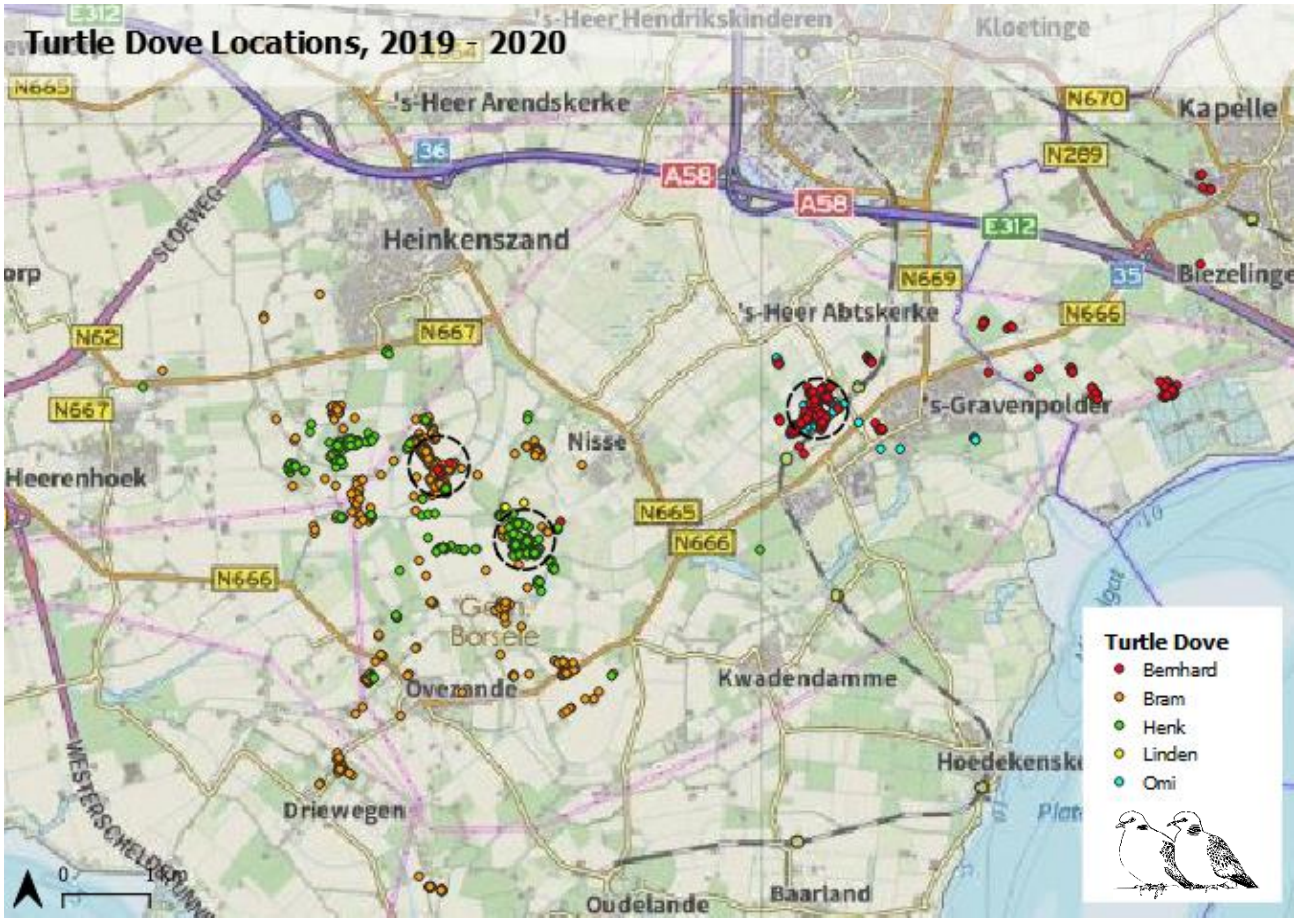


Figure 5: An unedited overview of datapoints collected in 2019 and 2020 (territories indicated)

There is a paucity of literature investigating the small-scale movements of turtle doves using high-precision telemetry loggers reliant on solar energy. How well the battery is able to recharge relies on independent factors such as weather, daylight hours, and how much time birds spend in the open. Since we were unable to predict, test or anticipate such factors in advance, the data collection intervals had to be tried and tested in the field in 2019. Consequently, intervals between recorded points vary greatly, from once every 3 minutes to once every 2 hours. In addition, when battery levels get too low, data recording is suspended until the tag has sufficiently recharged, resulting in a number of data gaps.

Each of the 5 tagged doves had a different breeding status and was followed during a different time period. While patterns in the doves' habitat choice can be identified, these trends are not necessarily representative of the wider population – additional data on a greater sample size would be required for this.

This analysis has considered each bird individually regarding their territory and home range, and communally when examining their foraging site choices. Some interesting insights have come out of this study, along with a better understanding of their daily movements and habitat preferences.

Data on Henk was collected up until his death around the 27th of August 2019. For the purposes of analysis, datapoints collected after the 23rd August have been excluded from the dataset. After this date, Henk's movements became noticeably shorter and less frequent. Further details regarding Henk's death can be found in Appendix 3.

4 Small-Scale Movements within Breeding Area

4.1 Home Range

The home range of an individual animal is the area in which they live and move on a periodic basis. In the case of telemetry datasets, this is taken to be the outermost datapoints, often in relation to the overall distribution of points. In the case of birds, the area of land inside the furthest coordinates is assumed to be accessible to them. Home ranges differ from territories in that they are *not defended* from others of the same species - a dove's territory makes up just a small area of their home range.

Home ranges were calculated using the entire data set available for each bird, and using the Concave Hull (alpha shapes) algorithm in QGIS. The 'threshold' was taken as 0.4 and, to account for the 15 m accuracy of the tags, a buffer of 15 m was added to the final home range perimeter.

Bernhard's home range, 2019

Bernhard's home range (Figure 6) in 2019, was 9 km^2, with his territory located right in the centre. It's interesting to note that the 5 western-most datapoints were only recorded towards the end of his stay in the Zak van Zuid-Beveland. While he had an active territory, his daily movements occurred around and due east/northeast of his territory. The northern-most points, on the other side of the motorway, are from visits to a grass-seed factory – one of Bernhard's regular foraging sites (Section 5.3). This factory, at 5 km away, is the furthest Bernhard flew from his territory to forage. Bernhard's behaviour saw a gradual change at the end of May, and he left the study area in early June. Since no nest was ever identified, it's suspected that he moved away due to his failure to breed (either through his lack of a partner or from a failed nesting attempt).

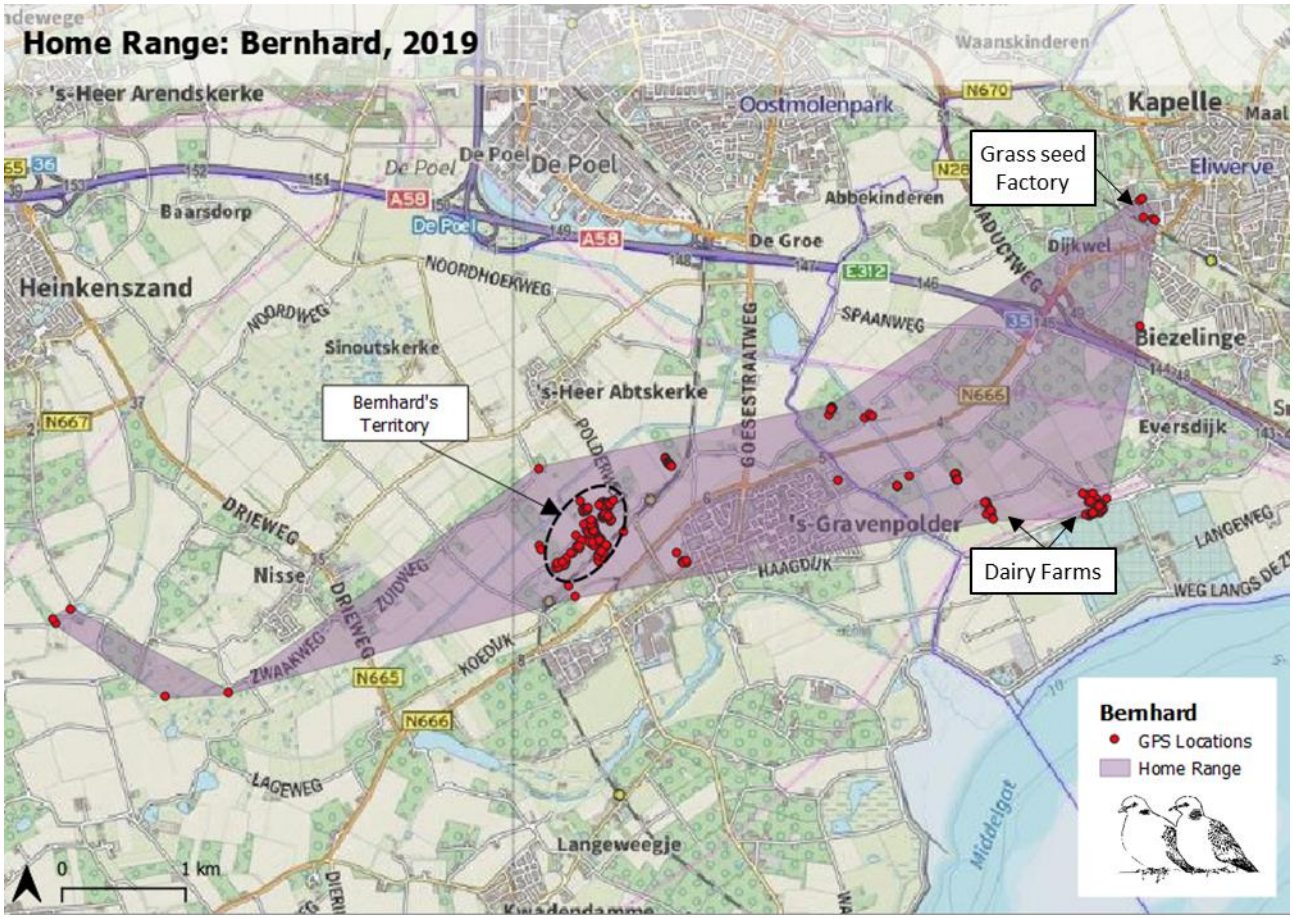


Figure 6: Bernhard's home range

Omi's home range, 2019

Omi's home range (Figure 7), at 0.9 km^2, was rather small. Had he stayed in the area for longer than 3 days his home range would have probably been much larger. Despite only providing data for 3 days, his dataset was still sufficient to identify a foraging site and his territory. Interestingly, the datapoints revealed quite a large overlap with Bernhard's territory (Section 4.2). Possible reasons for Omi's short stay in the Zak van Zuid-Beveland are a failed nesting attempt, lack of a partner, predation, or competition from Bernhard.

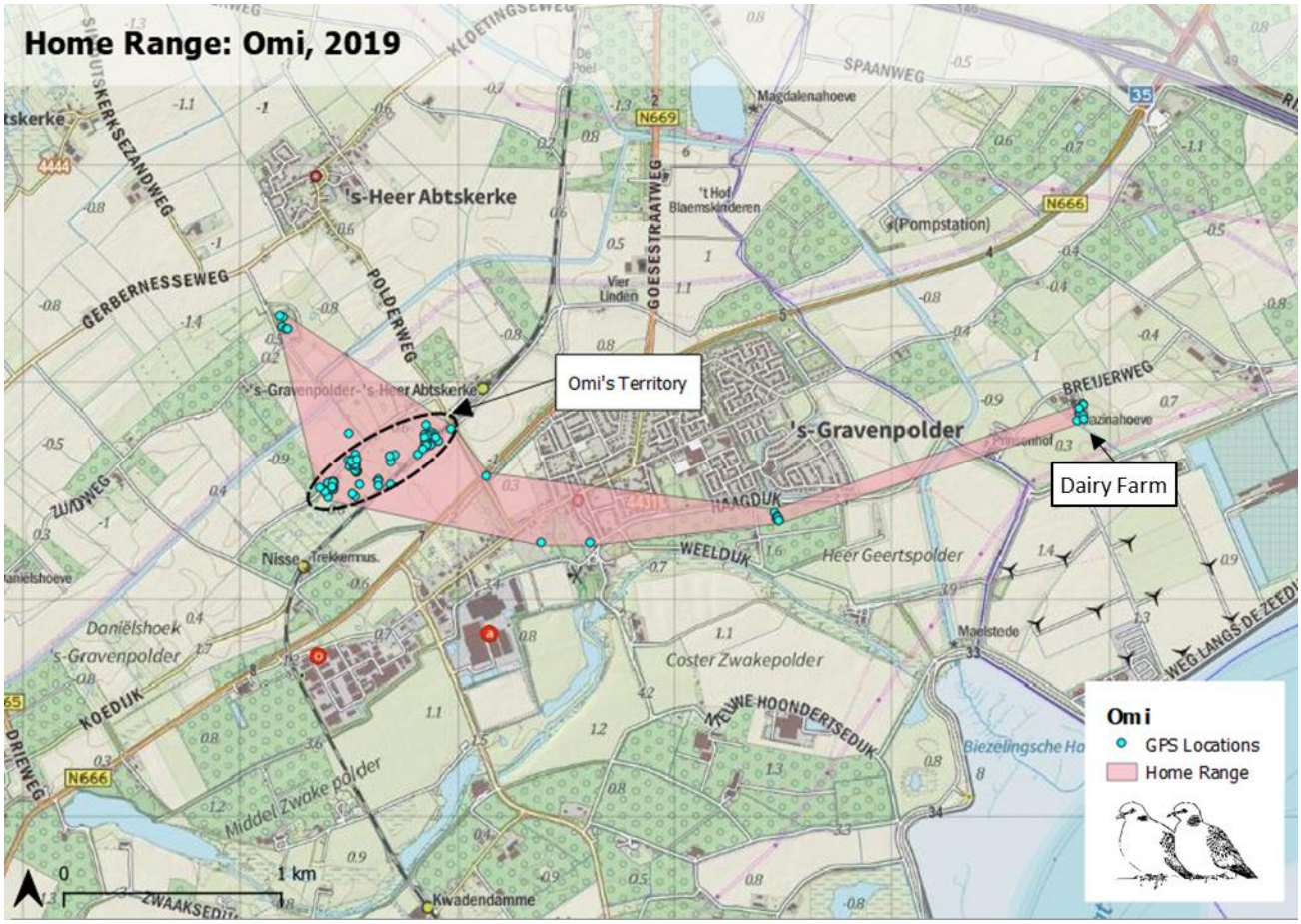


Figure 7: Omi's home range

Henk's home range, 2019

Henk's home range (Figure 8) was smaller than Bernhard's – more regular shaped, but less than 6.12 km^2. His movements tended to be due west/northwest of his territory, with his furthest foraging site 2.7 km from his territory. The second cluster of points, visible in the northwest corner of his home range, was a blue poppyseed field which he visited with increasing frequency from the end of July onwards (Section 5.6).

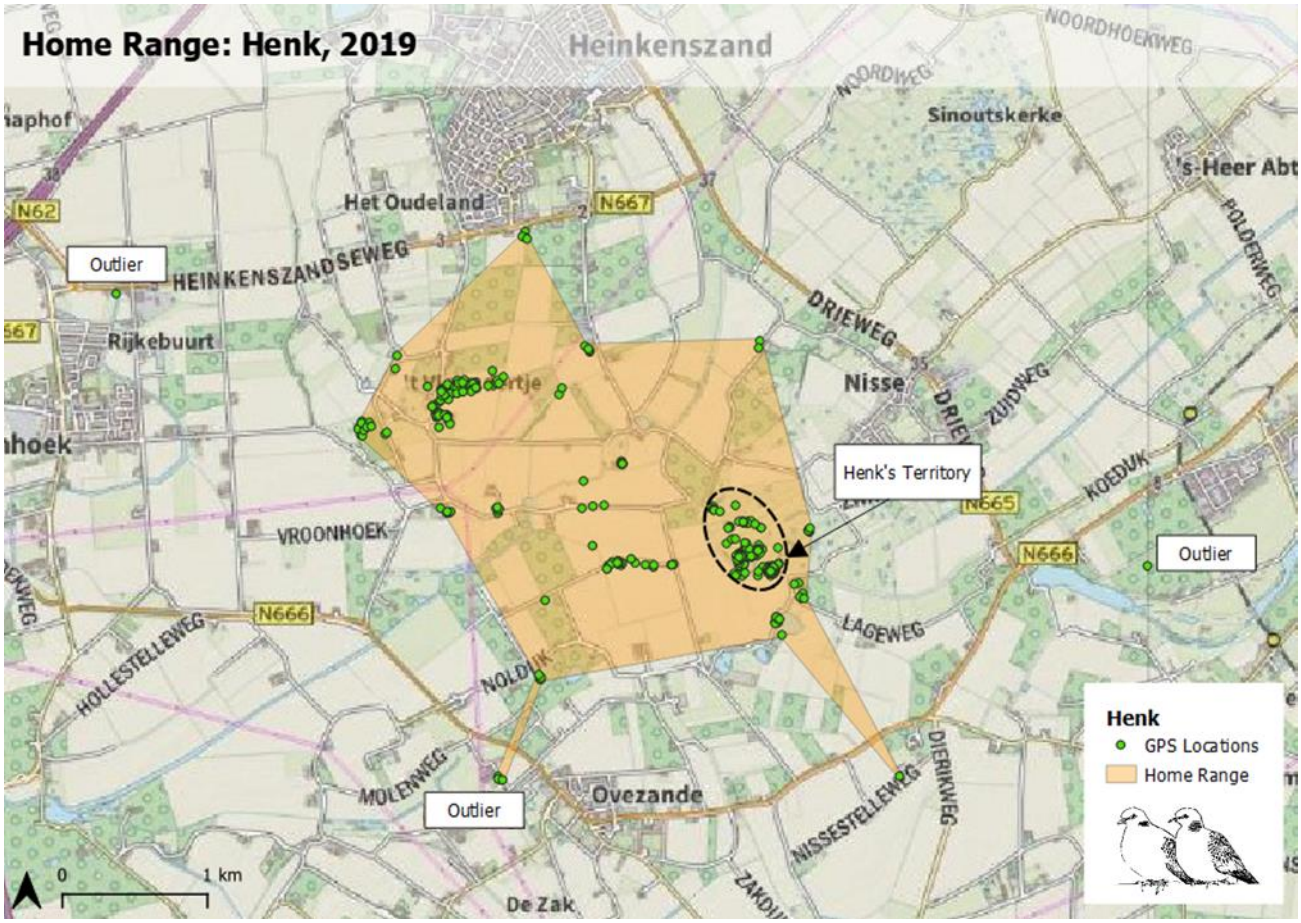


Figure 8: Henk's home range

Linden's home range, 2019

Linden, a young male born in 2019, had a very small home range of 0. 04 km^2 (Figure 9). His home range fell entirely within Henk's active territory in the Zak van Zuid-Beveland. This is typical of a young bird, as fledglings tend to remain close to the nest for the first weeks (Dunn et al, 2016). The fact that Linden's home range falls within Henk's territory is a strong indication that he was Henk's offspring (Appendix 4). All contact with Linden was lost after just 5 days of tracking, due either to predation or to Linden choosing to leave his nest site.

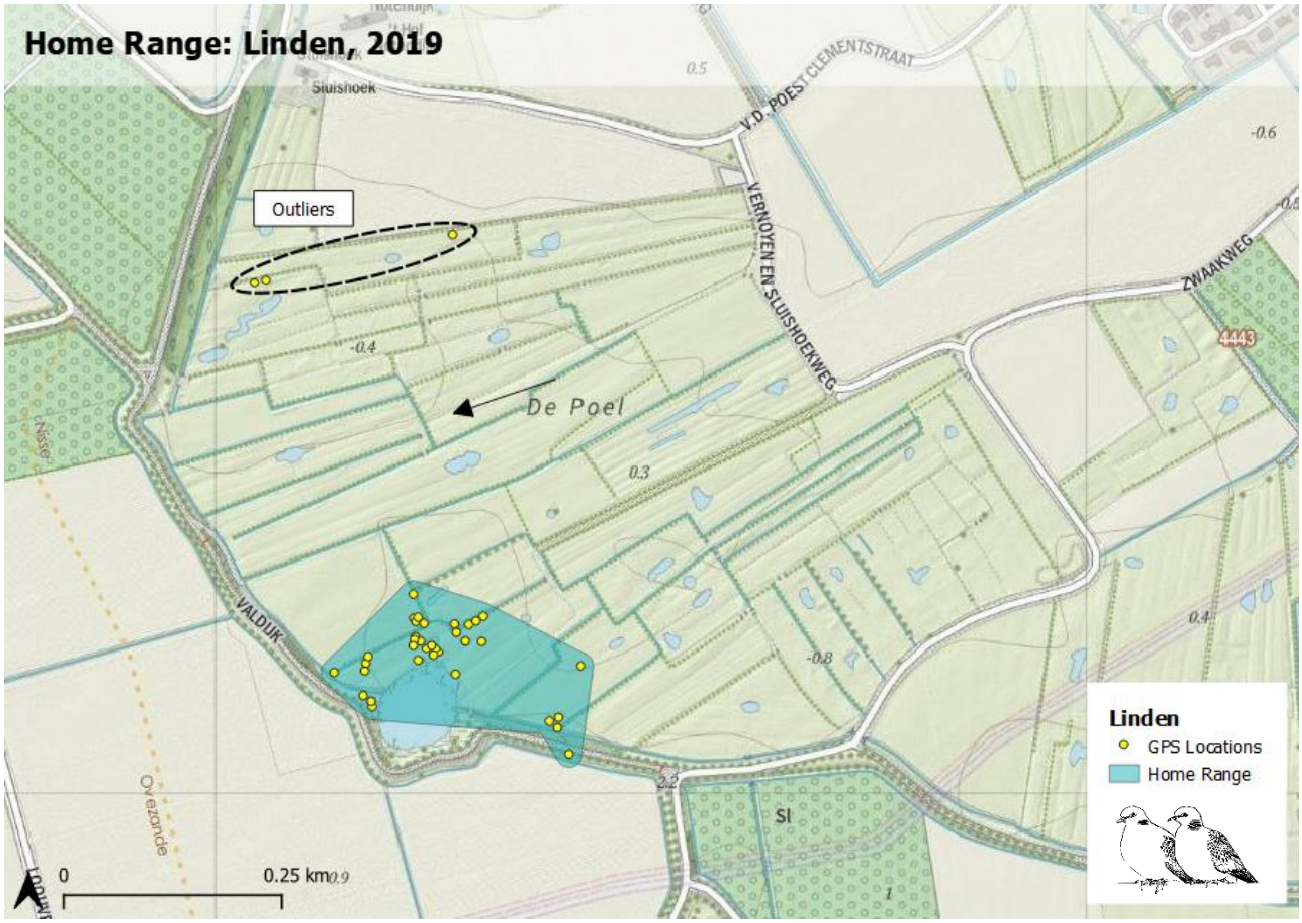


Figure 9: Linden's home range

Bram's home range, 2020

Bram's home range in 2020 was a sizable 13.43 km^2 (Figure 10). Earlier in the breeding season he would regularly fly 4 km to forage - the greatest distance recorded by his tag being 4.75 km south of his territory. Bram was behaving territorially when first tagged at the end of May, and his territory was quickly identified. His attachment to his territory, and enthusiasm for singing there, wore off towards the end of June and his behaviour became more 'wandering'. However, from the 24th June his behaviour changed again: he had an active nest.

Bram had 2 nests in total, within 150 m of each other. In both cases, the nests had a marked impact on his home range during the 2-week incubation period. While taking 'shifts' incubating eggs, Bram foraged for the most part within 1 km of his nest site. His home range for these periods was calculated using a concave hull algorithm (4.3 threshold) and a 15 m buffer. The resulting home range was just 2.44 km^2 (Figure 11). Once the chicks had hatched Bram gradually began foraging further away again.

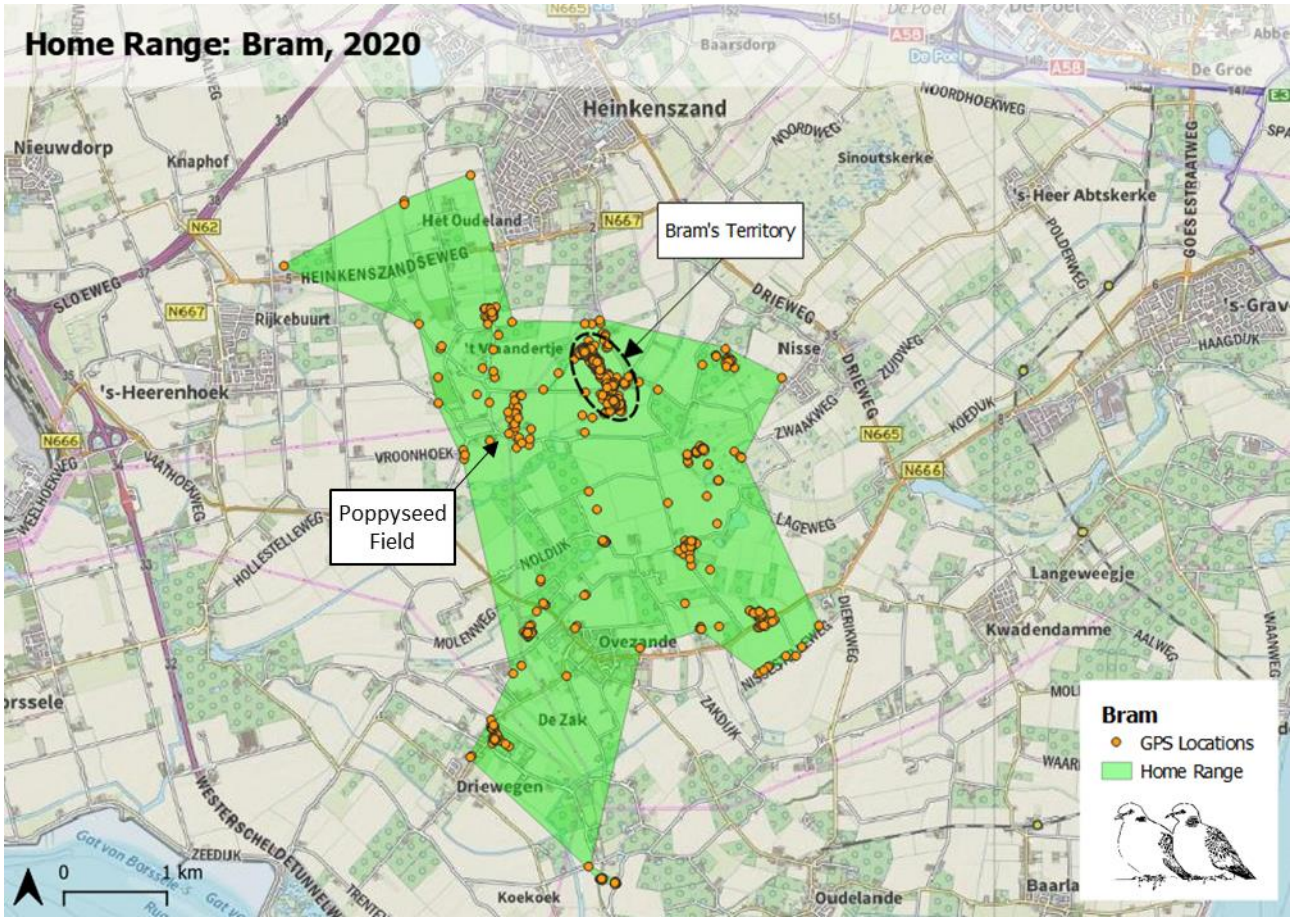


Figure 10: Bram's home range

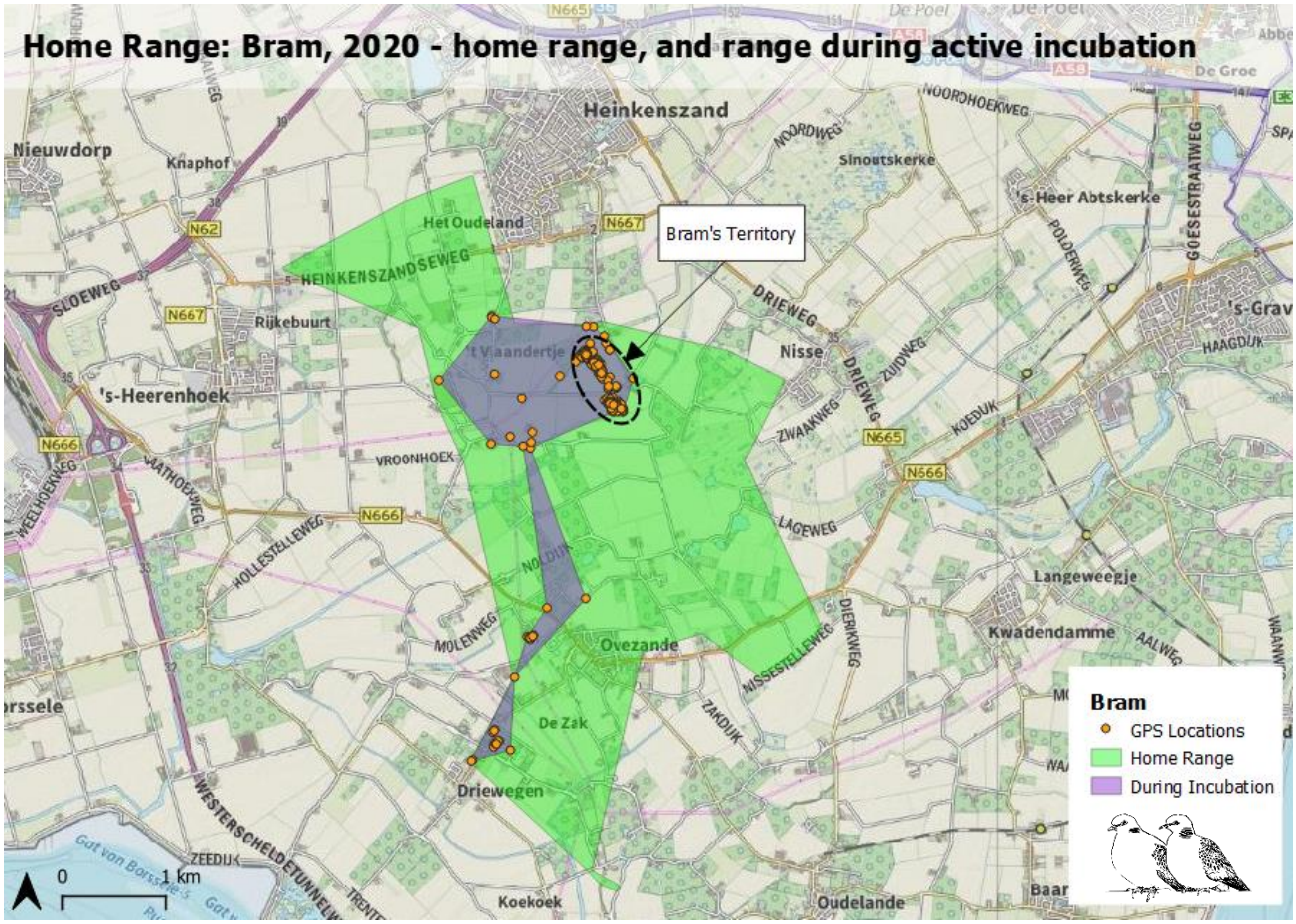


Figure 11: Bram's home range, compared to his limited range during egg incubation

4.2 Territory

An animal's territory is the area that it actively defends against others of the same species. This is different from a home range, which is the area that an individual uses on a daily basis for foraging. A dove's territory makes up just a small area of their home range.

With no means of determining what a dove was doing at any given datapoint, the identification of territories has been deduced using a combination of:

- The overall spread of datapoints: a territory will contain a high concentration of points.
- The knowledge that turtle doves will need to claim and defend their territory on a daily basis.
- The knowledge that turtle doves sing to announce their presence and claim a territory.
- The knowledge that turtle doves are diurnal, and are likely to roost in their territory.

Clusters were identified within each dataset and checked for roost points (coordinates recorded between 00:00 and 05:00) and daily activity. Using the QGIS "Paths-to-Points" function, each dove's movements were chronologically plotted on a map. Where a territory was present, these 'paths' indicated that the dove returned periodically, regardless of where they went during the day (Appendices 5, 6 and 7).

During field visits, doves were sometimes heard singing in a suspected territory. Field observations of territorial behaviour, such as singing and flight displays, were entered into waarneming.nl. These records were then later used to confirm the presence of a territorial turtle dove. On a few occasions the singing dove could be identified as one of the tagged doves.

Since it's difficult to determine precise territory borders, the minimum bounding geometry was calculated for each day. This provided daily territory boundaries based on the dove's movements around his territory area (Appendices 8 to 11). Where these daily boundaries had significant overlap, and taking the aforementioned factors into consideration, a line of 'best fit' was used to define each territory.

Of the 5 monitored turtle doves, 4 were territorial adult males – Linden, as a young male, was not expected to have a territory in 2019. Bernhard, Henk and Bram provided sufficient information to define a territory. Omi's data and behaviour indicated a territory, but he disappeared 3 days after being tagged so the 'best fit' territory boundary for him is less accurate.

Bernhard's territory (Monitored 13 May – 2nd June)

Data providing insight into Bernhard's daily movements is available for the second half of May 2019. Bernhard had a clear territory, located on Bergweg. His territory was approximately 11 ha (0.11 km^2), situated in a small-scale landscape with 2.5 km of overgrown mixed hedges containing trees. The largest land parcel in the area is less than 2 ha.


Photos: Bernhard's territory

The territory (Figure 12) was dominated by grassland (85%) – a mixture of privately owned nature areas, including land from Natuurmonumenten, and fields for grazing sheep and horses. Other land uses include small amounts of rural buildings and gardens (3%), train track (2%) and road (5%). The majority of Bernhard's points were linked to taller trees, scrub and hedges (Appendix 12). There was also nearly 800m^2 of water in the form of pools and ponds within Bernhard's territory. The shape of his territory mirrored the land uses of the surrounding area: he clearly avoided cropped fields and orchards, and focussed his attention on the hedge/tree rich, small-scale landscape, grassland dominated areas.

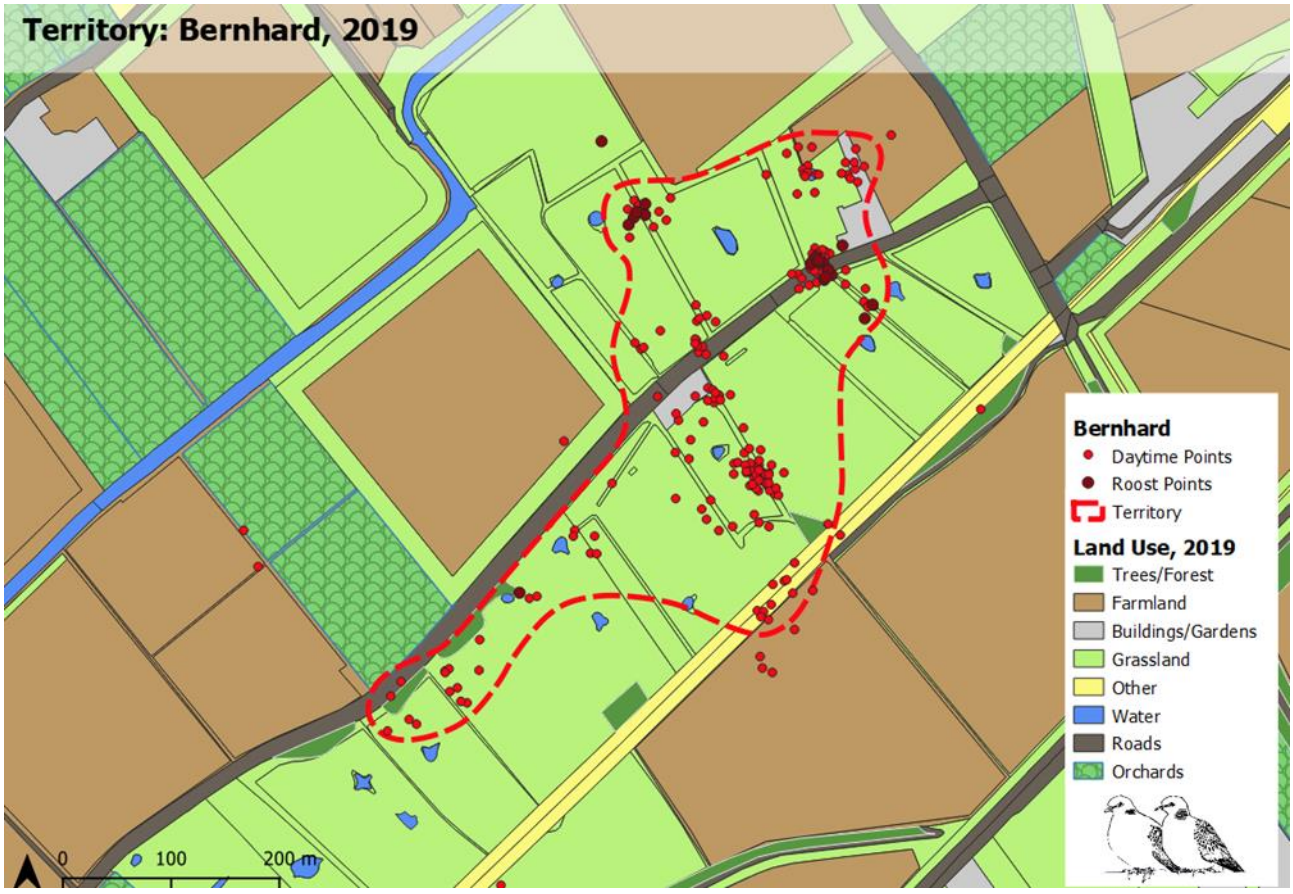


Figure 12: Land use map of Bernhard's territory

Bernhard's coordinates from the end of May/early June indicated a big shift in his behaviour, just before contact was lost. Most notably, he no longer returned to his territory, even to roost. He also began visiting entirely different areas during the day compared to those visited in May. This data, combined with the loss of contact with him, suggests a failed breeding/nesting attempt on Bergweg and a subsequent move away from the territory. Without additional data it's impossible to know if he attempted to set up a second territory in 2019.

Omi's territory (Monitored 14th May – 16th May)

Omi was captured at the same feeding station as Bernhard, just 1 day later. His dataset indicates that most of his time was spent on Bergweg. Despite the fact that he only stayed in the study area for 3 days after tagging, he appeared to have an established territory. As with Bernhard, Omi had a tendency to stay close to tall trees and hedgerows (Appendix 13).

As with Bernhard, the bulk of his territory was characteristic of a small-scale mixed grassland landscape. Although Omi's territory was less than half the size of Bernhard's, at 5.4 ha (0.05 km^2), it still contained more than 1 km of hedges. Grassland comprises 85% of the land use - both natural grassland and grazed, with a further 5% of the land use made up of road/track, 5% of railway, and 3.5% of deciduous woodland (Figure 13).

Photos: Omi's territory

Interestingly, Omi's territory had a large overlap with Bernhard's (Figure 14). However, individual locations within the territories were dominated by one or the other dove. There were 3 clusters of points in Omi and Bernhard's overlapping territory (13th-16th May), each cluster being heavily dominated by just 1 male. The two males were not frequenting the same trees. With only a few days' worth of data from Omi, his territory was only temporary. Since it was abandoned so quickly it wasn't possible to investigate this territory overlap in more detail. It is possible that Omi moved on because of competition from Bernhard.

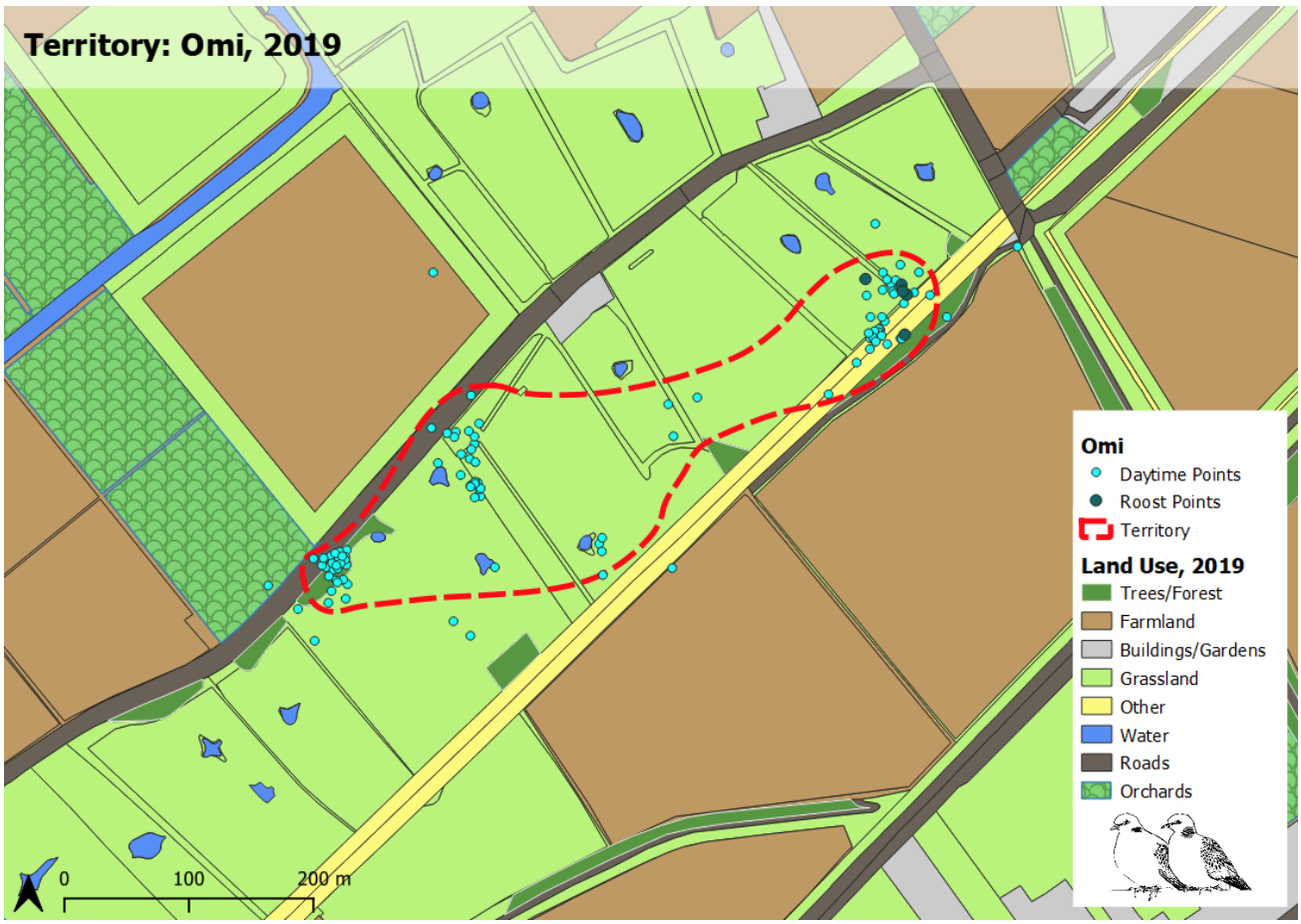


Figure 13: Land use map of Omi's territory

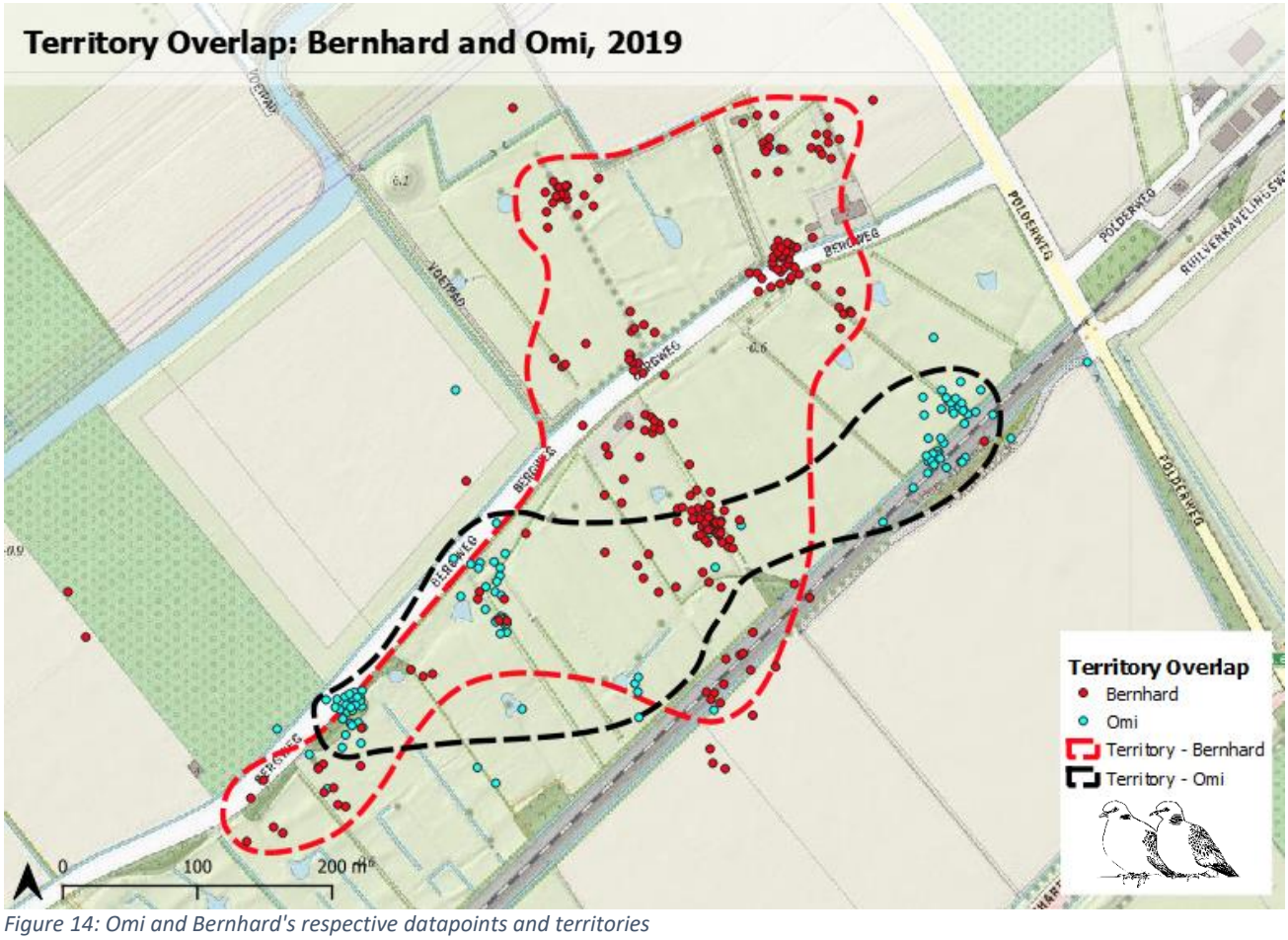


Figure 14: Omi and Bernhard's respective datapoints and territories

Henk's territory (Tracked 1st July – 27th August)

Henk was captured relatively late in the breeding season but his data revealed a strong territory right through to the 11th of August 2019. Henk's territory was located in the Heggengebied – a small-scale landscape owned predominantly by the nature organisation Natuurmonumenten. Henk's comparatively small territory of 3 ha (0.03 km^2) was located in Natuurmonumenten owned land parcels and contained more than 0.5 km of overgrown, mixed scrub and trees. This 500 m is not including all the scrub and trees around the large, permanent pond.

Henk's territory comprised largely of natural grassland, which covered 79% of the area (Figure 15). A further 14% of Henk's territory was made up of ponds and pools. Trees/scrub, and roads/tracks made up 5% and 2% of the territory respectively. As with the other doves, Henk's datapoints were most concentrated around areas of trees, hedgerows and scrub (Appendix 14).

Photos: Henk's territory

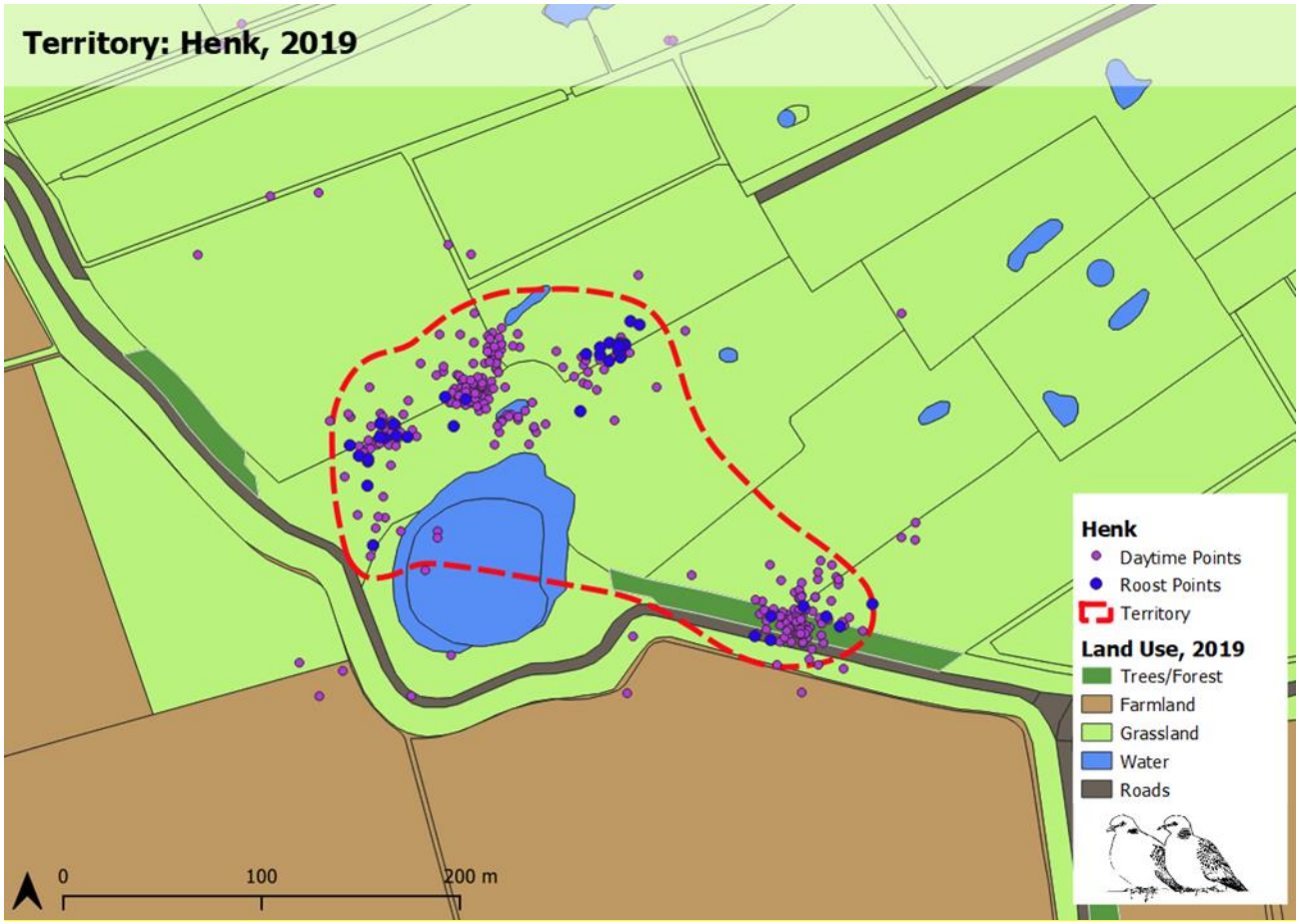
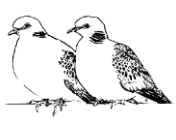


Figure 15: Land use map of Henk's territory

Henk roosted here for the most part, with the occasional use of a pond (less than 500 m away), and a single night spent at location 2 km away. His occasional absence from his territory might be because it was the end of the breeding season and he was subsequently less attached to the area. There are a number of points which were ultimately discounted from the final 'best fit' territory boundary. A detailed justification of these can be found in Appendix 15.

After the 11th August, Henk's behaviour changed. The 11th to 16th August saw a shift in his roosting locations; despite continued daily visits to his territory, and he started frequenting a location more than 2 km away**.** Henk's datapoints from the 17th to 23rd August indicate a complete behavioural shift: he abandoned the Heggengebied and took to roosting at different locations, with no obvious attachment to a specific area. An annotated map of Henk's movements during his last weeks of monitoring can be found in Appendix 16. As discussed in Chapter 3, datapoints recorded after the 23rd August were discounted; Henk became ill and this visibly impacted his behaviour in the days before his death.



Bram's territory (Tracked 30th May – 17th September)

Bram was tagged at the end of May 2020 and, uniquely, remained in the study area for the whole breeding season, successfully fledging 2 nests of chicks. Prior to nesting, Bram established his territory in an area dominated by grassland and a small holding. His nest locations were nearby (less than 500 m away) and located in unmanaged scrub growing along a dike. Either side of the dike was cultivated, with orchard growing on one side, and crops on the other. For the purposes of analysis, Bram's territory was calculated based on his point distribution throughout the whole season, including his 2 nests where he obviously spent a lot of time. The resulting territory (Figure 16) had a size of 7.8 ha, and was dominated by grassland (37%) and orchard (31%). It also contained a significant amount of farmland (20%) and small amounts of road, buildings and farmyard. Bram's territory had more than 1 km of overgrown scrub and hedge, with trees growing through it, and more than 600 m of trees bearing the wide, open canopies favoured by doves. As with the tagged turtle doves in 2019, the bulk of Bram's points are clustered around the scrub and taller trees (Appendix 17).

Three large clusters of datapoints can be seen within Bram's territory, indicating the areas where Bram spent the bulk of his time. The largest cluster is around the small-scale landscape of the small-holding where he was tagged. He frequently foraged here, particularly earlier in the breeding season (Section 5.9). The two smaller, more dense clusters indicate his 2 nests, both of which were located in overgrown scrub that runs along the edge of the orchard.

Figure 16: Land use map of Bram's territory

Territory: land use composition

Figures 17 to 19 show overviews of the land uses in each dove's territory in 2019, when no tagged dove had an active nest. In addition to grassland, all sites contained roads and tracks, and small amounts of woodland. This was in agreement with the findings of Browne and Aebischer (2004), who found that turtle doves in their study area had territories containing a higher proportion of woodland, grassland and non-crop habitats than expected by chance.

While the percentage of woodland as a land use is rather low, as a landscape feature taller trees proved rather significant. All territories were scattered with trees, overgrown hedges and scrub. Each territory had the highest concentrations of turtle dove points around these features. Their clear preference for these areas reflects "the species' behaviour of loafing near the nest-site or in tall trees and hedges, which is also where most territorial behaviour is conducted." (Browne & Aebischer, 2005). It is safe to conclude that they are of great importance, not just as nesting habitat but also for territorial behaviour and resting.

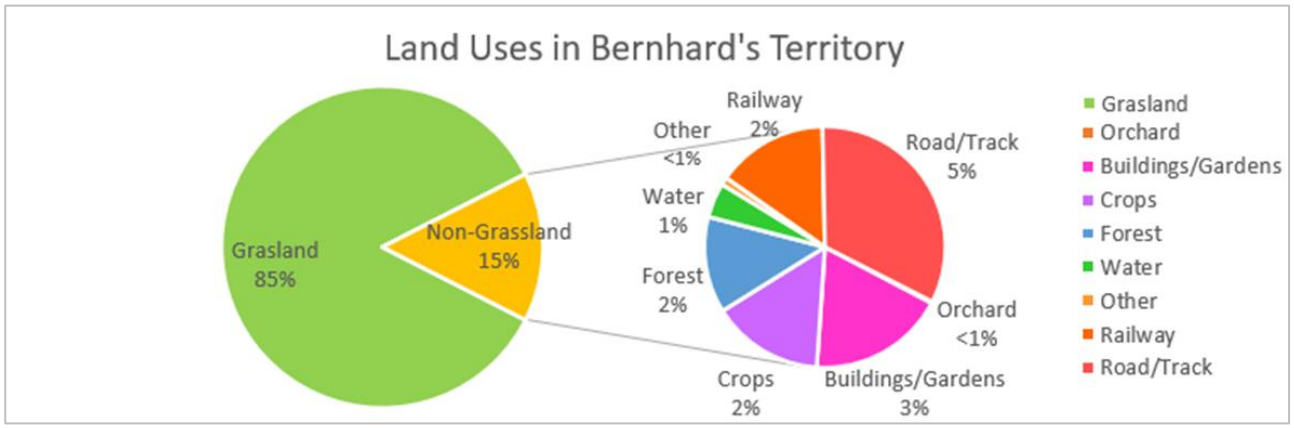


Figure 17: The percentage of each land use in Bernhard's territory

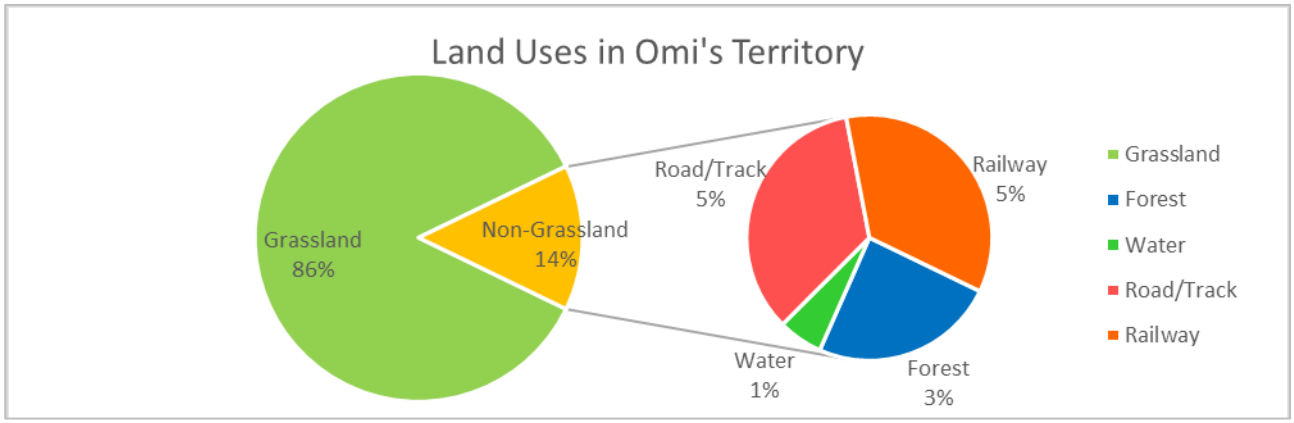


Figure 18: The percentage of each land use in Omi's territory

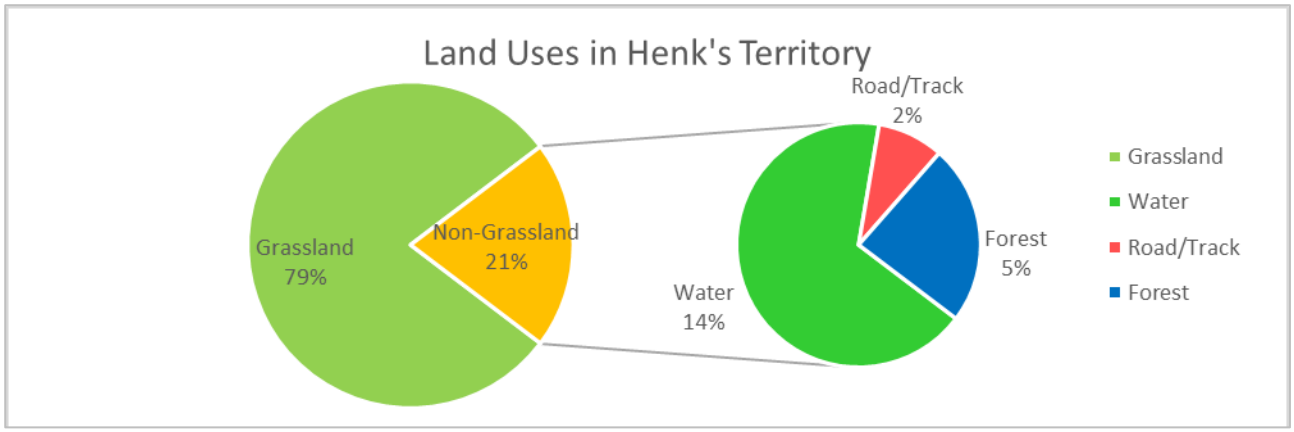


Figure 19: The percentage of each land use in Henk's territory

The land use composition for Bram's territory in 2020 is illustrated in Figures 20 and 21. Prior to nesting, Bram's territory reflected a land use composition similar to those of 2019 (Figure 20). However, once his territory was calculated to include his nest sites, the land use 'orchard' suddenly made up almost a third of his territory (Figure 21), and 'crop' land use became strongly represented.

While Bram's territory does include orchard and crops, it is important to note that Bram's use of these land uses is limited: he makes more use of the grassland areas, and his activity is most concentrated around the scrub and trees. Bram's territory had more than 1 km of overgrown scrub and hedge, with trees growing through it, and more than 600m of trees bearing the wide, open canopies favoured by doves (illustrative height map in Appendix 18).

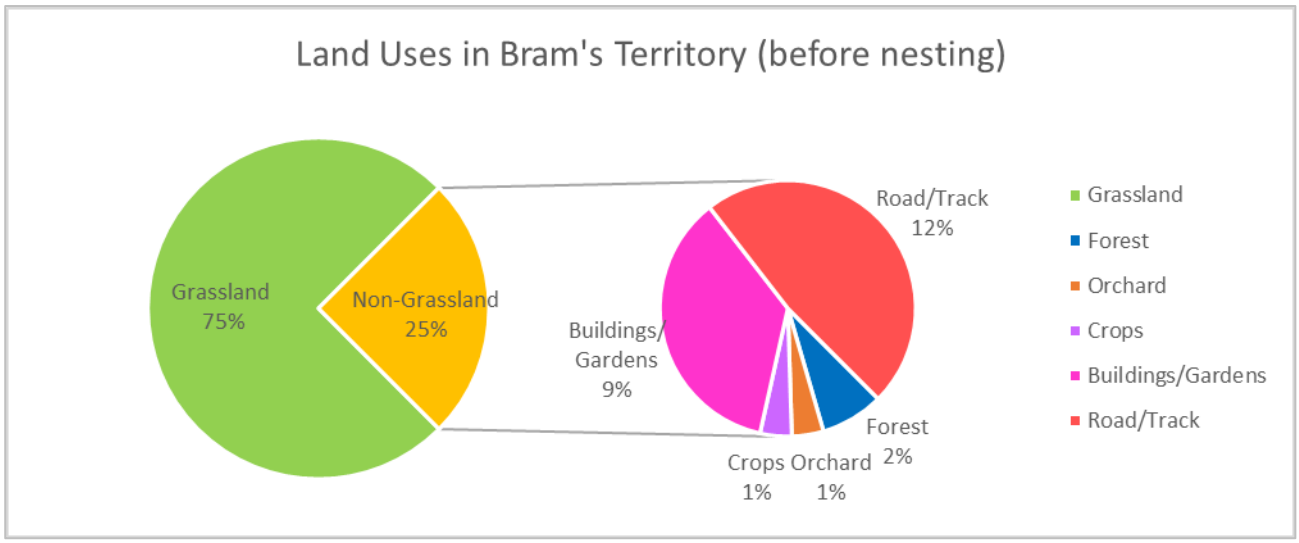


Figure 20: The percentage of each land use in Bram's territory prior to nesting

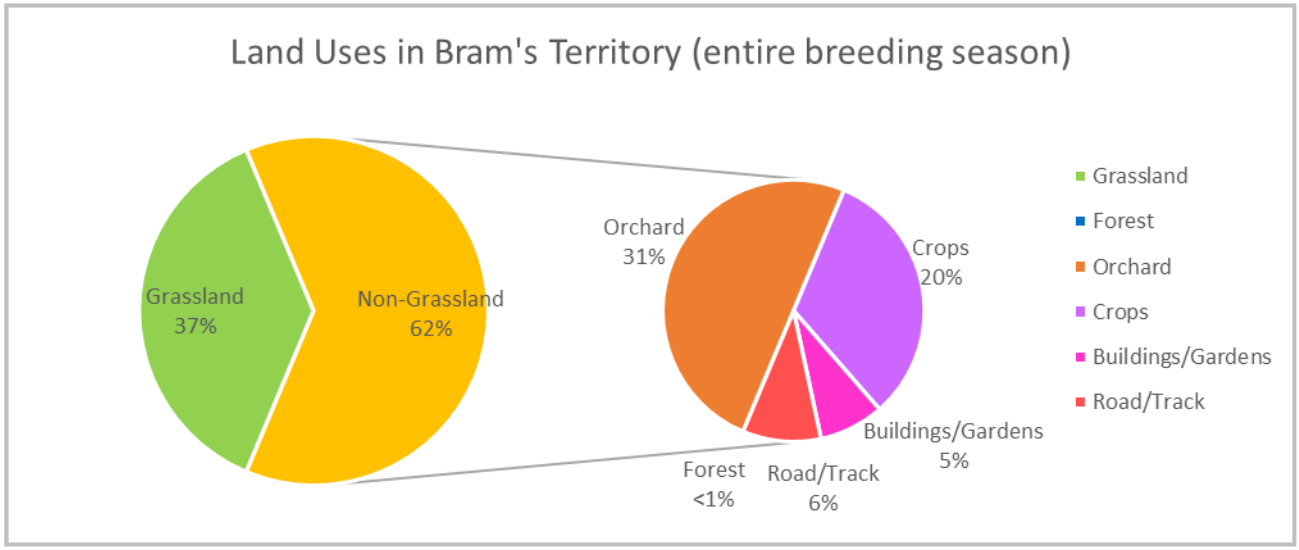


Figure 21: The percentage of each land use in Bram's territory including nests

Territory: land use composition vs. availability

Browne and Aebischer (2003) observed that the nesting territories of turtle doves had a higher proportion of non-crop habitats, such as woodland and grassland, than was generally available at their study site. Similarly, this research found the territories of tagged turtle doves to contain a much higher proportion of grassland than was generally available in their home ranges (Figures 22 and 23). While this is noteworthy, it is unclear whether there's a direct link between grassland presence and territory selection: there are likely additional factors involved. For example, in this study area, specific land use features might be more common in areas that also contain grassland.

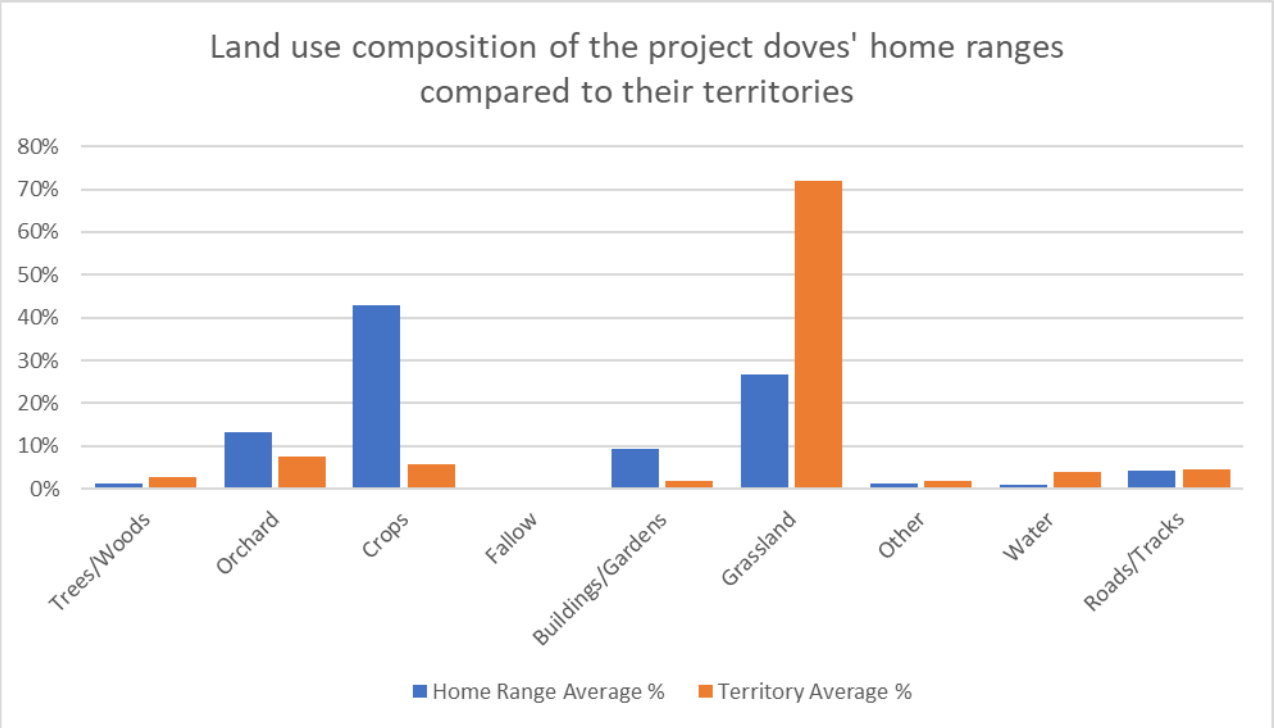


Figure 22: Average availability of different land uses within the home ranges and territories of tagged turtle doves.

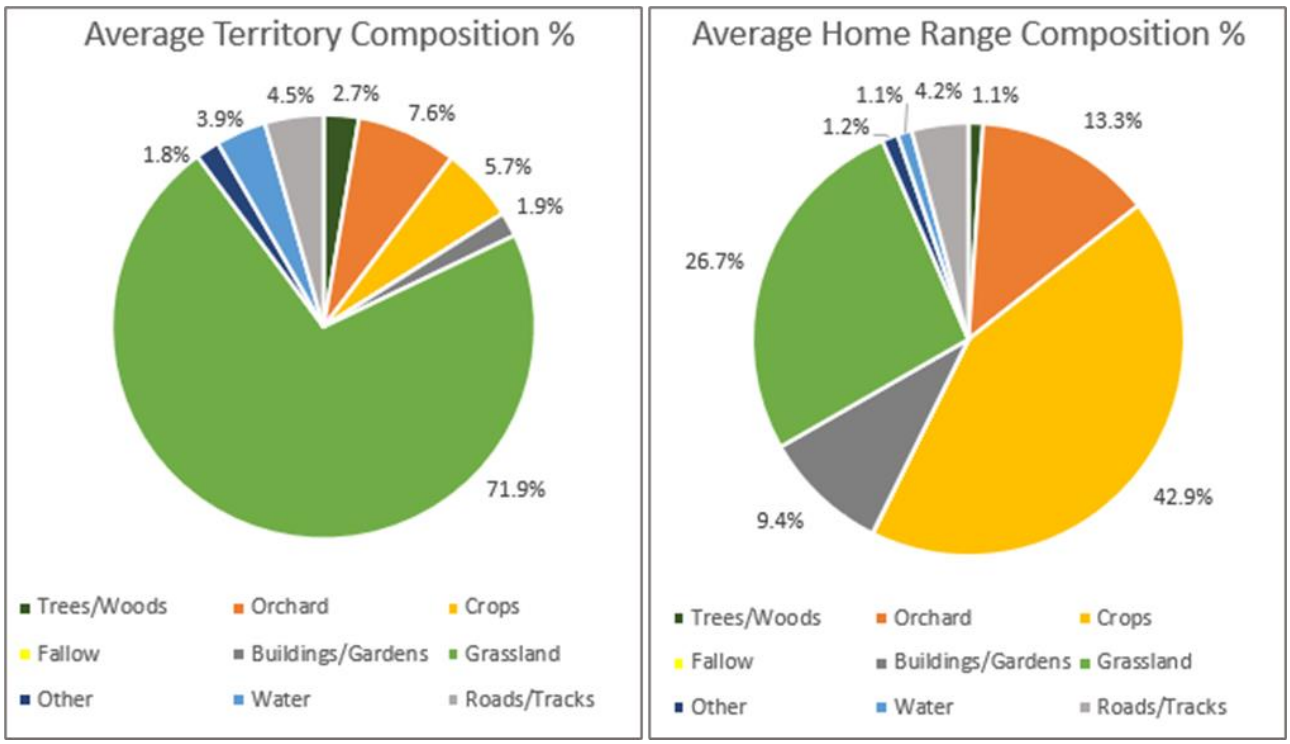


Figure 23: Average territory and home range composition (%)

Nesting Habitat and Locations

During the course of this research 2 nests were located, both from Bram in 2020. No nests were identified in 2019: contact with Bernhard and Omi was lost before they could nest, Henk is thought to have just finished a nest, and Linden was born in 2019.

Bram's 2 nests were located 2-3m above the ground, in overgrown hawthorn scrub that separated an apple orchard from a dike. The site neighboured a small holding where Bram had initially established his territory. The dike was managed as a public footpath by nature organisation Natuurmonumenten, with a narrow gravel track and herb rich grass verges either side, subject to seasonal mowing. The dates of Bram's 2 nests have been estimated based on Bram's behaviour, combined with estimated chick ages during field visits (Table 3). Nest disturbance was kept to a minimum during the start of egg incubation and after the chicks were more than 10 days old, to reduce the risk of nests being abandoned or premature fledging. The estimated dates concurred with literature: Browne & Aebischer (2004) found that turtle doves incubate their eggs for about 2 weeks, and that chicks remain in the nest for 10 to 19 days before fledging.

Nest Attempt	Number of Chicks	Start of Incubation	Hatching Date	Last date chicks observed in the nest
1	2 chicks	24 June 2020	11 July 2020	21 July 2020
2	1 chick	4 August 2020	18 August 2020	28 August 2020

Table 3: Approximate timing of Bram's 2 nests in 2020

Photos: Bram's first nest and chicks, 2020

Dunn et al (2016) found that fledglings spend more than half their time within 20 m of their nest site for the first 3 weeks after fledging, and make most foraging trips (95%) within a 329 m radius. From this perspective, Bram occupied ideal nest sites. While the nests themselves were in the dense, thorny branches of hawthorn trees, surrounding the

nest site was a variety of habitats, situated between the orchard and cropped field either side of the dike (Figures 24 and 25). This high concentration of habitats such as track, weed-rich grass and scrub is typical of what you might see in a small-scale agricultural landscape. It was also noted that the grass either side of the footpath contained species such as bird vetch, white clover, camomile, cock's-foot grass, meadow and creeping buttercup, and black medick - all of which are known to be eaten by turtle doves.

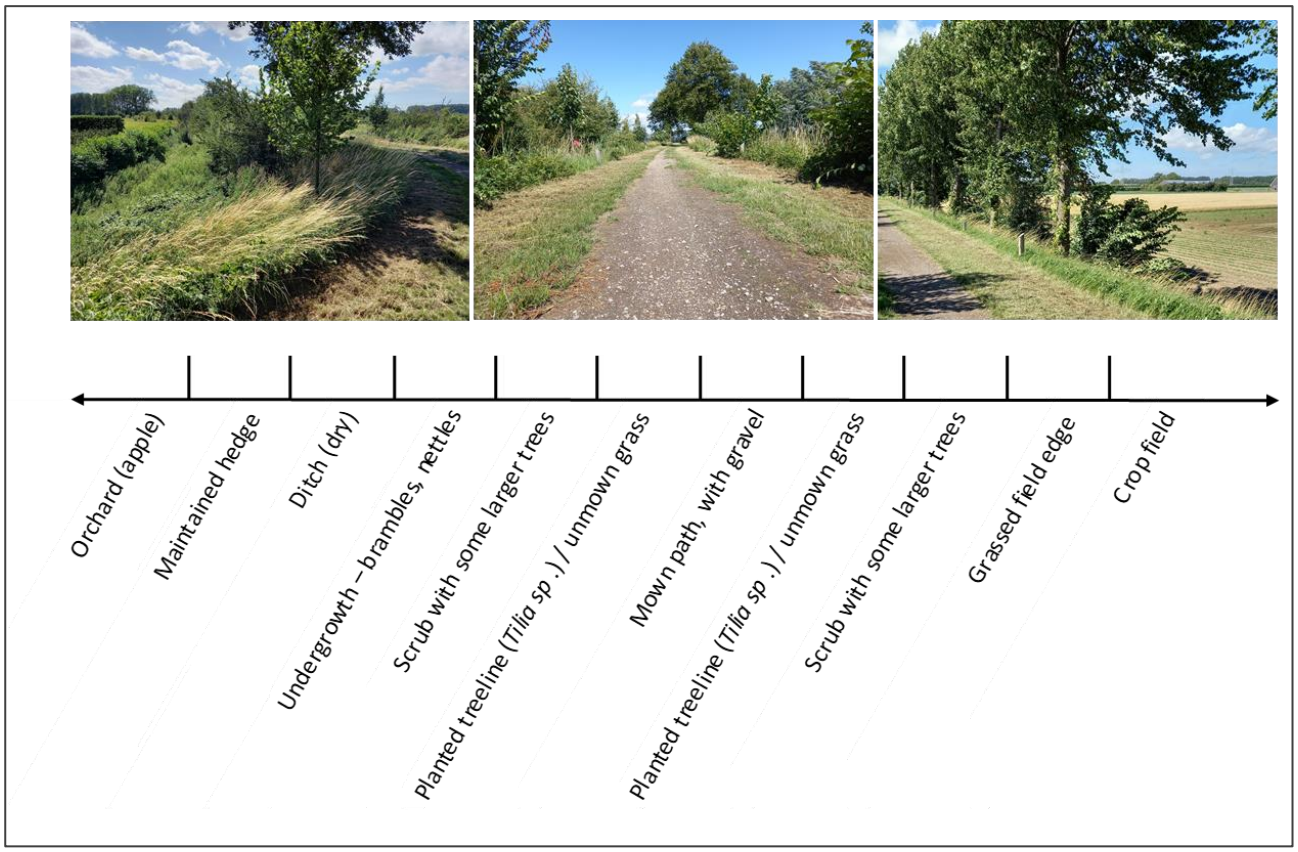


Figure 24: Habitats in the immediate vicinity of Bram's nests

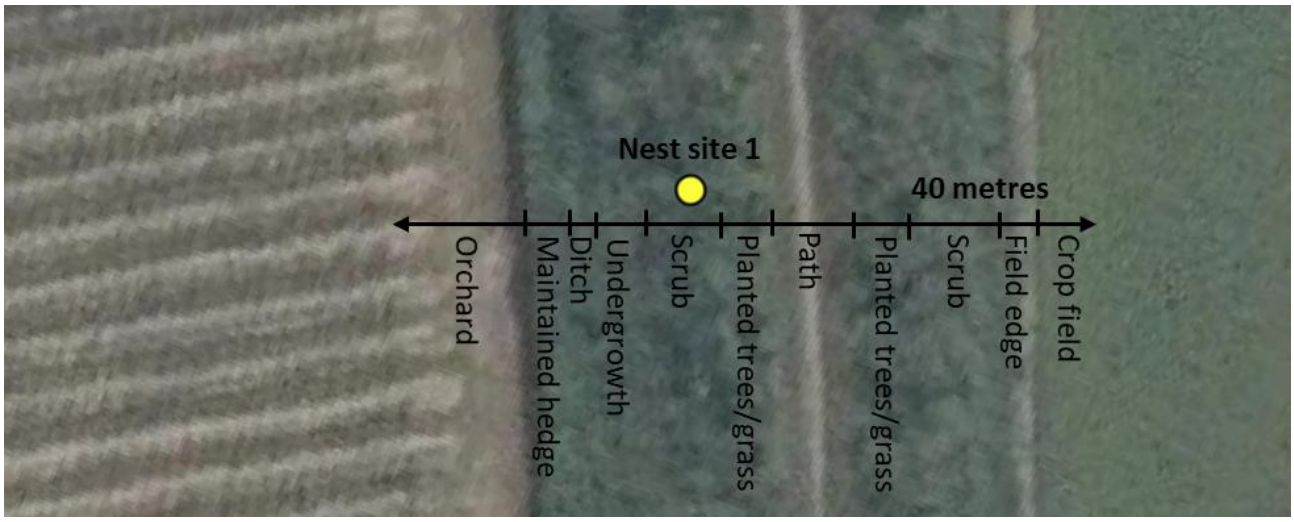


Figure 25: Habitats in the immediate vicinity of Bram's nests

While Linden's exact age is unknown, his home range fitted entirely into Henk's territory, and more than half of his datapoints fall within a 50 m radius of a corner of hedgerow in the Heggengebied. The hedgerow here was more than 4 m high and dominated by blackthorn and hawthorn. There were also a few taller trees protruding from it, and bramble growing around the base. According to the literature (Browne et al, 2005; Dunn et al 2012; Kleemann et al, 2014) this would be suitable nesting habitat for turtle doves. If Linden was a fairly recent fledgling, staying in close proximity to his nest site (Dunn et al, 2016), then it's most likely his nest was in this hedge.

5 Where do they Forage?

Turtle doves are granivorous and feed primarily on the seed of wild, low-growing weeds and spilt crop seed (Browne and Aebischer, 2003). They are known to prefer short, sparse vegetation with a high percentage of bare ground.

Rather than focussing on each dove's individual foraging site choices, all foraging sites will be investigated together, on the basis of their land use/s. This chapter focuses particularly on recurring land uses in order to examine the following questions more fully:

- Where do turtle doves in the Zak van Zuid-Beveland forage?
- Are there any similarities between the landscape and/or land uses at foraging sites?
- Are there any trends in foraging site choice over time?

5.1 Identifying Foraging Sites

Using the complete dataset of all tagged doves in 2019 and 2020, foraging sites were identified in 4 steps. The first step was to eliminate all points where there was reasonable certainty that the dove was not foraging. This meant:

- Removing all roost points (recorded between 00:00 and 05:00)
- Removing all flying points (altitudes over 15 m and/or speeds of over 10 m/s)

To get as unbiased an insight as possible into their foraging site choices, feeding stations used as 'bait' during the capture process were quickly built off once the doves were tagged. Nevertheless, both Omi and Bernhard were known to visit an active feeding station not far from their territories. This led to the second step: the removal of all datapoints within 15 m of an active or recently active (within 3 days) feeding station.

The third step was to discount points within 20 m of each dove's territory. While this process discounts any foraging points located within their respective territories, it limits the risk of classifying resting/singing/nesting points as foraging points. Incidentally, only Bram was observed foraging in his territory, alongside domestic poultry at a small holding. This small holding foraging site is detailed in Section 5.9, independently of other foraging sites. Points further away than 20 m were all considered to be potential foraging points, since the main reason for an adult male turtle dove to leave his territory would be to drink or forage.

Using professional knowledge, the final step was to identify clusters (points in close proximity to each other and/or occupying the same land parcel) where a dove had visited repeatedly or else stayed for a long period of time (>2 hours). While this step will likely underestimate the number of foraging sites, it aims to exclude locations that doves didn't stay at, or return to, thereby identifying only the "most interesting" foraging sites for doves.

Once clusters of points were identified, it became clear that 9 clusters were not actually foraging sites, but rather roosting sites. All points in these clusters were from a single late-evening and early-morning of the following day, and often included a 'roost point' (a point recorded during the night). The doves subsequently never returned to these sites, indicating their limited foraging value. These clusters have been excluded from this analysis.

Clusters of points were buffered by 15 m (to accommodate tag accuracy) and the outermost points joined together, creating what is hereafter referred to as a 'foraging site. This process revealed 48 foraging sites: 24 from 2019, and 26 in 2020 (Figures 26, 27 and 28). Each site has been allocated a numerical code for this analysis – a detailed list of sites and their respective codes can be found in Appendix 19.

Henk's dataset contained 12 foraging sites over the course of the 8 weeks that he was tracked. Bernhard's dataset revealed 10 sites, 3 of which are located in close proximity to each other. While most of Omi's time was spent at the Bergweg, his behaviour indicated territorial rather than foraging activity. Consequently, only 1 foraging site was identified for Omi. Bram was tracked for the entire 2020 breeding season, and his dataset revealed 26 foraging sites.

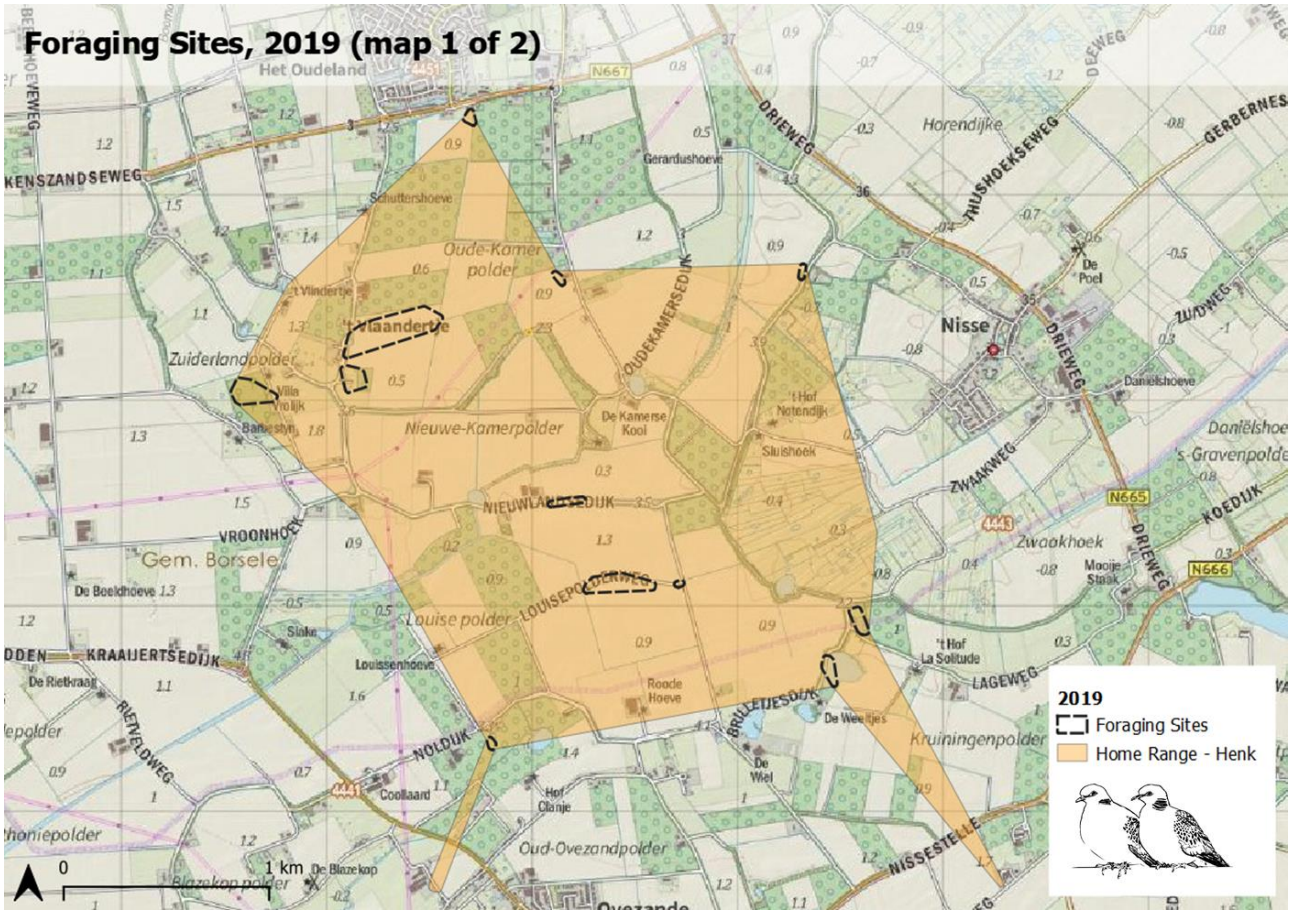


Figure 26: Foraging sites, 2019

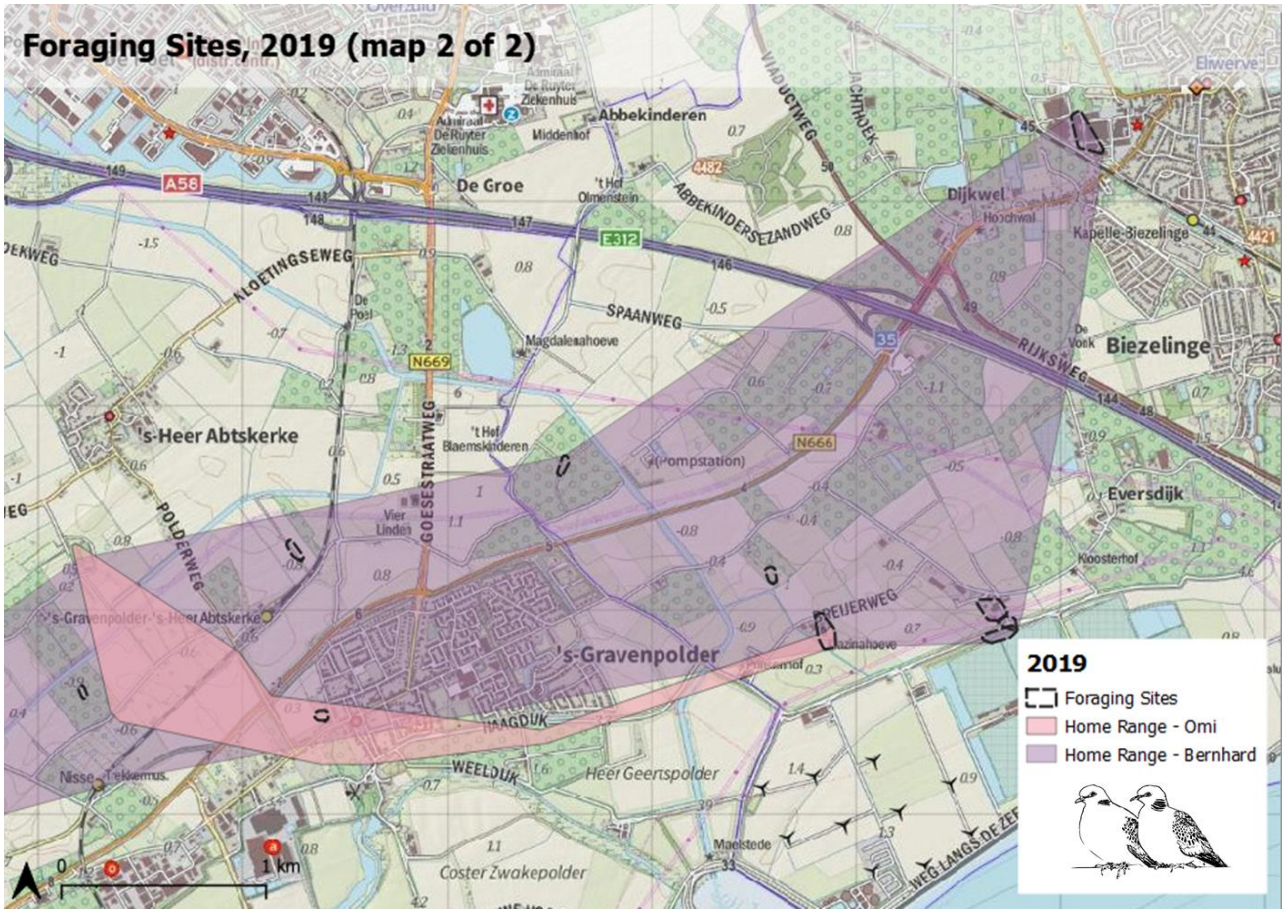


Figure 27: Foraging sites, 2019

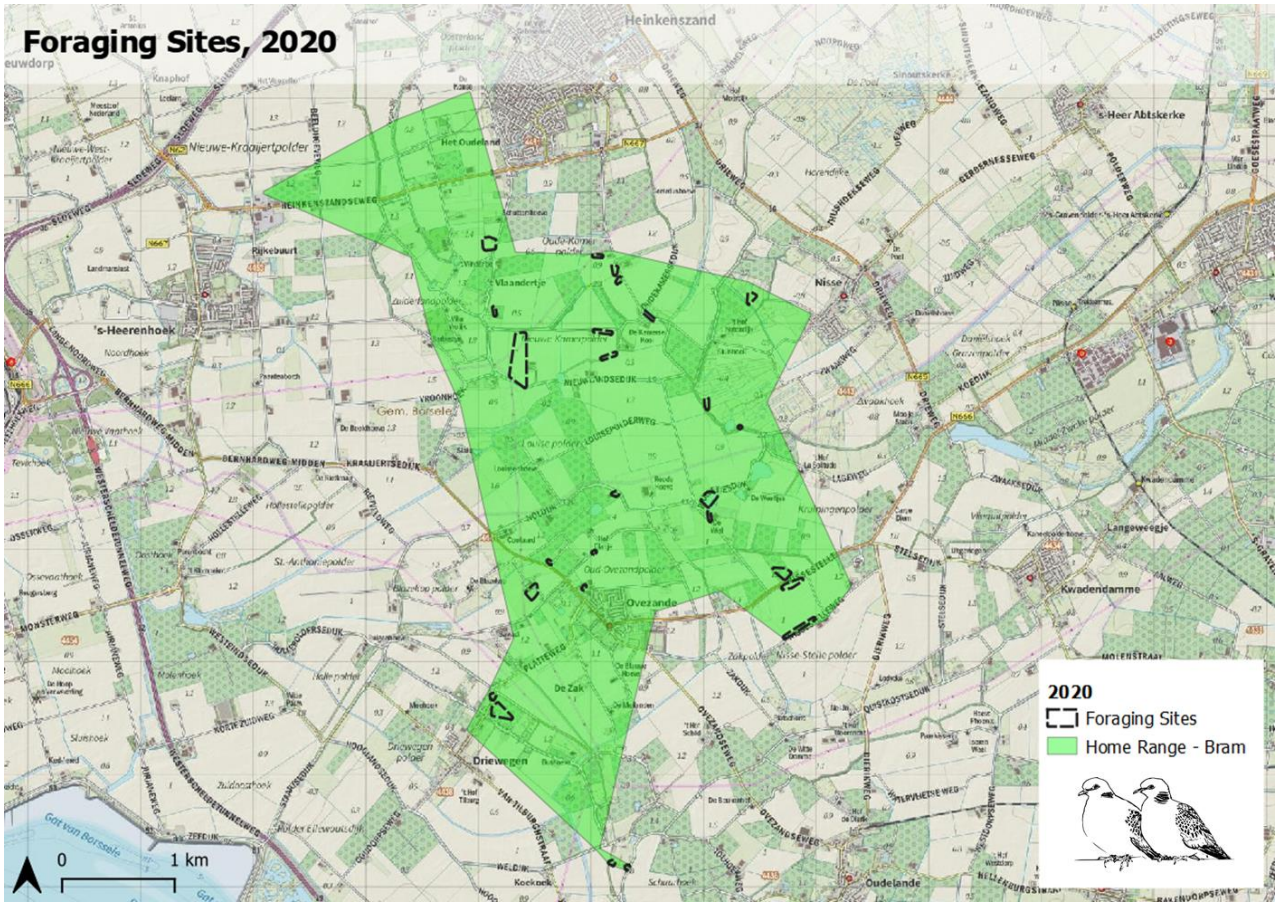


Figure 28: Foraging sites, 2020

5.2 Dominant Land Use

A land use map was created for each year of the project by compiling data from different sources (including annual agricultural data). This data was then assigned into categories and sub-categories considered relevant for gaining insight into turtle dove foraging habitat (Appendix 20).

In the breeding seasons of 2019 and 2020, 48 foraging sites were identified, representing a variety of land uses. Most foraging sites had several land uses. Crops, grassland and road/tracks were the most frequently occurring land uses, and green manure fields, fallow land and other were the least frequent. Simply looking at the land uses per site was not enough to identify the preferences of the project turtle doves; it simply indicated that most foraging sites contained grassland and crops.

Considering the number of sites dominated (>75%) by a particular land use, or sites with an even mix of land uses, provided some indication of where the project turtle doves were foraging at (Figure 29). The majority of sites (23) were mixed land use and were made up of combinations of grassland, orchard, crops, roads/tracks, woodland, water and buildings/gardens. The remaining foraging sites were dominated by a particular land use.

The most interesting observations and trends only emerged once the distribution of turtle dove datapoints was considered and compared on a site-by-site basis. The rest of this chapter considers each of the main land uses, with particular focus on those sites where it was dominant.

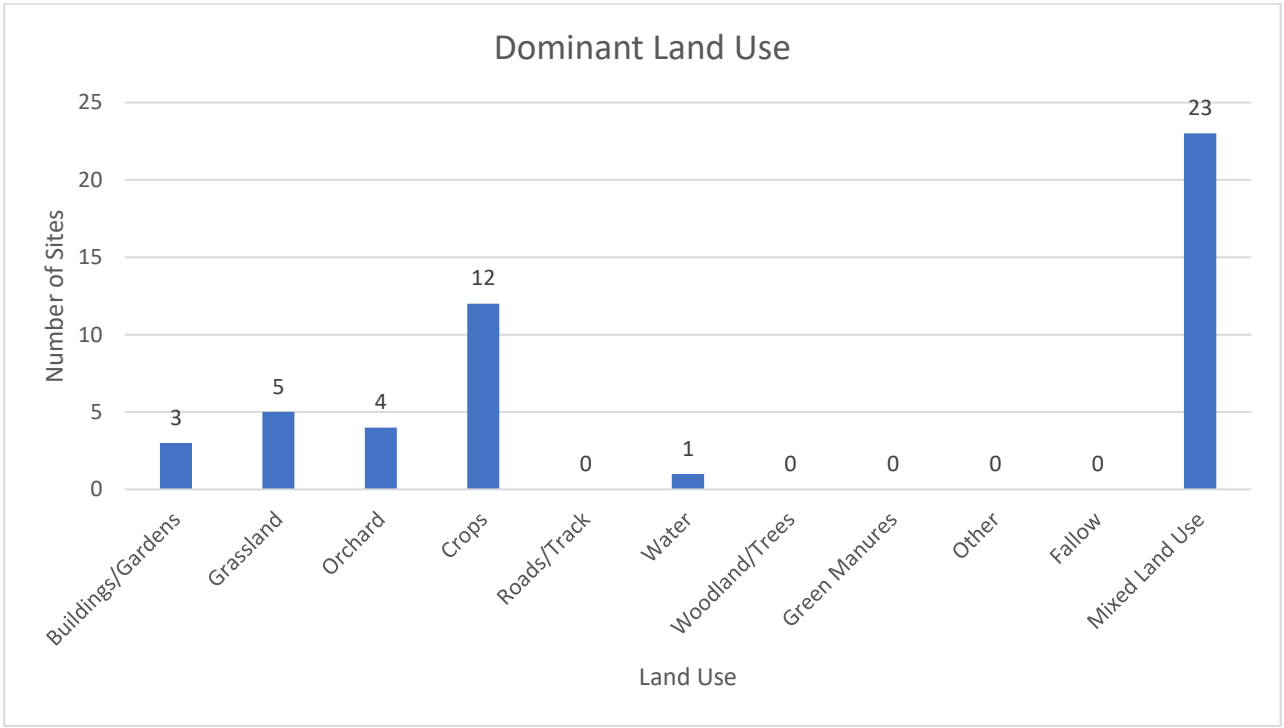


Figure 29: Number of foraging sites where a land use covers more than 75% of the area (or else contains 'mixed land use')

5.3 Buildings and Gardens

Of the 48 foraging sites, 20 possessed some form of building/garden land use. All the sites where buildings/gardens were present were rural or semi-rural - the turtle doves didn't enter towns or cities. At the majority of these sites the doves showed little interest in the actual buildings, with the exception of a grass seed factory on the outskirts of Kapelle. Farmyards (3 dairy, 1 orchard) were visited regularly by Bram, Omi, and Bernhard earlier in the season. Here, the doves focussed their attention on areas of high seed availability: spilt or stored seed, and weed-rich corners of the farmyard.

Where gardens were present, the doves made occasional use of the trees and hedges, with the exception of a cluster of gardens on Schuitweg. This mixed land-use site, located on the outskirts of 's-Gravenpolder, was visited regularly by Bernhard in July, and the owners kept chickens and a vegetable garden which might explain its appeal to Bernhard. The rest of this section provides details and photos of the more unusual foraging sites containing (or dominated by) buildings and gardens.

Grass Seed Factory

Bernhard visited the DLF grass seed factory on 4 days in May. At 5 km away from his territory, it is the furthest he travelled to forage. This location tests, processes and stores a wide variety of different seeds and seed can be found on the ground around the site. An investigation of the site revealed that the warehouse doors are sometimes open, leading to a variety bird species coming to forage here. All Bernhard's visits occurred after 5pm: this might be indicative of the doors being open at certain times of day, or the site being quieter after this time. It might simply be that the site was not interesting enough to visit more often; perhaps it wasn't worth the flight when closer alternatives were available. As seen in Figure 30, Bernhard is recorded at 3 locations. Points A and B both have trees/bushes that would offer shelter. Point C is, from the end of May, where trucks containing grass seed are unloaded.

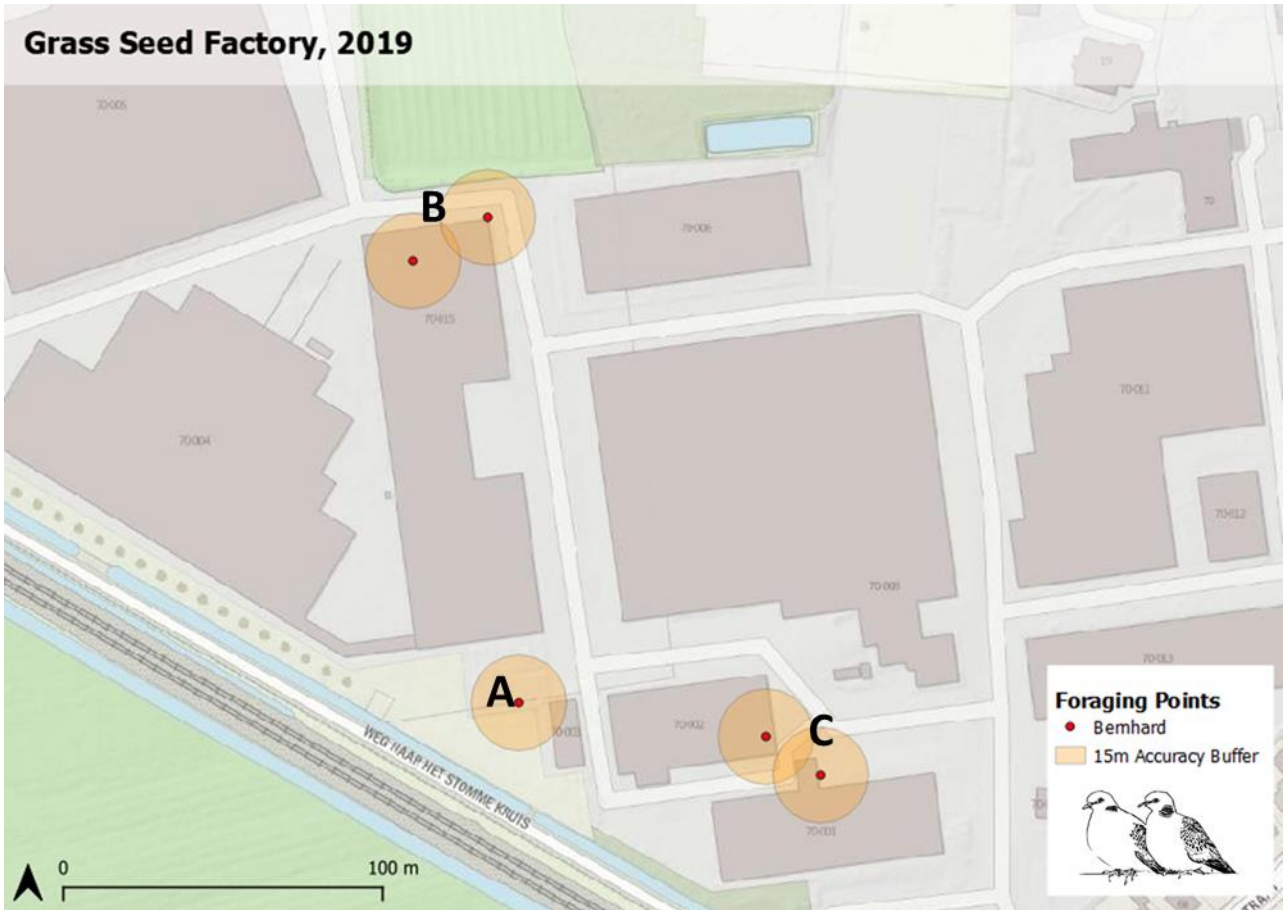


Figure 30: DLF Grass Seed Factory, Kapelle

Farmyards

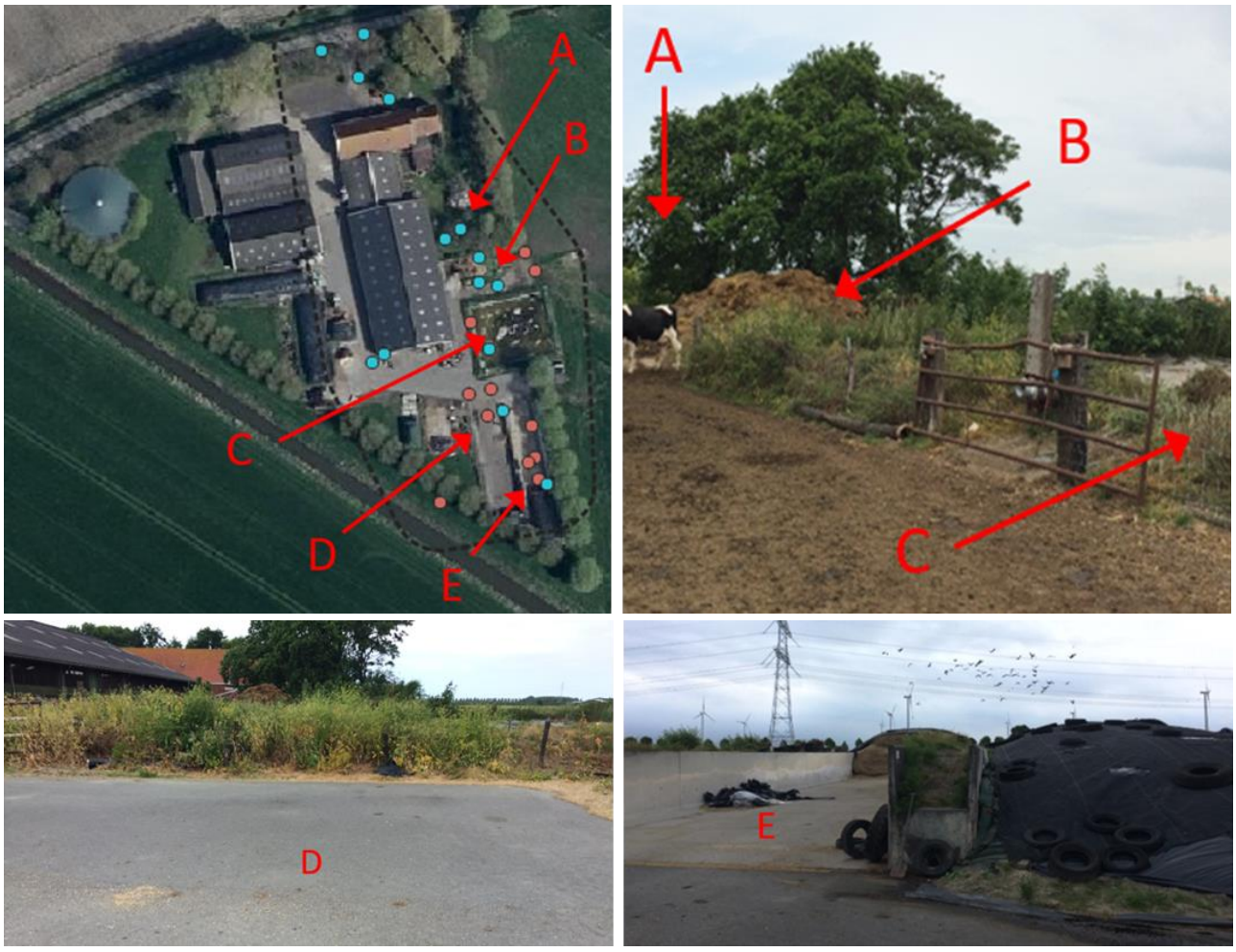
Four farmyards (3 dairy, 1 orchard) were of particular interest to Bernhard, Omi and Bram – paved areas surrounded by the farmhouse, farm buildings, silage heaps and garden. It is interesting that these farmyards were popular, given that farms are generally busy and rife with dogs, cats, people and machinery. All but one datapoint was recorded before the end of June, suggesting a lack of 'natural' alternative foraging sites before July. This was similarly observed by Browne and Aebischer (2003), who found that turtle doves were using farmyards earlier in the season, when grain was being moved (and spilt) from storage barns. It's possible that Bernhard, Omi and Bram were here for similar reasons.

At all 4 farms, the doves showed particular interest in areas of scrub, taller trees, paved farmyard, weed-rich corners, manure heaps and silage heaps. The silage at all 3 dairy farms was silage maize. At the Everdijkse Bredeweg farmyard, turtle doves were witnessed foraging in the silage channel and flying back and forth to a large nearby plane tree when disturbed. While not observed, comparable behaviour was identified with Bram at the Ruigendijk-Korteweg orchard farmyard, suggesting the tall trees of a neighbouring garden were being used as shelter.

Breijerweg Dairy Farm, 2019

On the Breijersweg farmyard, the dove's points were concentrated:

A) In taller trees and scrub
B) On a paved area next to a manure heap
C) Around a covered slurry pit surrounded by weeds and with water pooling on the cover. A wagtail was seen drinking here so perhaps this location was as much a source of water as it was seed.
D) On the paved farmyard between the silage channel and barns
E) In the open (eastern-most) silage channel – the western silage channel was covered with black plastic and tyres in May/June and was fairly inaccessible.



Photos: Breijerweg Farmyard

Everdijkse Bredeweg Dairy Farm, 2019

On the Everdijkse Bredeweg farmyard, the dove's points were concentrated:

A) Around white and green bales
B) In the farmyard by the barn doors
C) Around the slurry pit (covered and collecting water)

In addition to Bernhard's registered datapoints, he was observed foraging around the chopped maize in the silage channel and flying to the large plane tree just south of the farm when disturbed. This must have been a regular occurrence given the number of points clustered around the tree.

Photos: Everdijkse Bredeweg Farmyard

Oude Noordweg Dairy Farm, 2020

The Oude Noordweg farm was visited almost daily by Bram in late June 2020. This farm was also a working dairy farm but had several corners which were not maintained/disturbed/cleaned. These wild, unkempt areas clearly worked to the advantage of Bram as they provided plenty of spilt food, abundant weeds, abandoned hay bales, bare ground and overgrown scrub/taller trees. Bram's data points were predominantly around:

A) Areas of overgrown scrub/taller trees
B) Abandoned ground between the silage channels and treeline
C) The farmyard, where additional food/compost heaps were located.
D) Barn entrances, where spilt silage and large puddles were found.

Bram's 2020 behaviour at the Oude Noordweg dairy farm differed slightly to Bernhard and Omi's dairy farm visits in 2019. Instead of focussing his attention on the silage channels and spilt grain, Bram seems to have focussed on a patch of adjacent ground (area 'B'), suggesting that this unkempt corner of farmyard provided better foraging opportunities.

Area B had an abandoned feel to it: the surrounding scrub/trees appeared unmaintained and contained dead wood, the grass and weeds were tall and uncut, abandoned hay bales were bursting out of their plastic wrapping, and old machinery had been left. This weed-rich, marginal environment might have been too dense for Bram to exploit if it weren't for one crucial detail: the abandoned machinery had burnt out here a few years previous, killing the closest trees and creating a large patch of bare ground around it. This had subsequently created the open, sparse, pioneer type of environment perfect for both weeds and foraging turtle doves. It is little wonder that Bram visited this site frequently in late June, when the weeds would have been coming into seed.

Photos: Oude Noordweg Farmyard

Ruigendijk - Korteweg Farm and Orchard, 2020

This foraging site, visited by Bram in 2020, was split between 2 land uses – buildings/yard, and the orchard. Points around the built-up portion of this site* were concentrated around:

A) A dumping area
B) The yard

*Orchards will be covered in Section 5.5.

The dumping area was a mixture of bare soil, weeds, and old wood. The yard in front of the machinery barn was obviously not subject to regular weed control, and had many weeds growing around the paved area. Species such as black medick (*Medicago lupulina)*, herb-Robert (*Geranium robertianum*), prostrate knotweed (*Polygonum aviculare*) and white clover (*Trifolium repens*) were present, as well as a few stray cultivars such as potato and barley.

Photos: Ruigendijk - Korteweg farm/orchard

Gardens

Schuitsweg Gardens, 2019

This foraging site was made up partly of gardens and partly of grassland. The doves showed as much interest in the gardens as in the grassland. The gardens containing a chicken run and a small allotment/landscaped beds were the most visited, likely because of the availability of bare ground, weeds and chicken seed.

Photos: Schuitsweg gardens/grassland

5.4 Grassland

Grassland was present at 30 out of the 48 foraging sites, but almost entirely in the form of narrow strips along road verges or dikes. Where present, the doves showed interest in this marginal grassland habitat - unsurprising given that road verges are one of the relatively few areas where weeds grow in abundance and the vegetation is sparse.

Photos: Marginal grassland verges at various foraging sites

A few sites did not fit this trend, including the aforementioned Schuitweg garden/grassland site (Section 5.3), and grazed grassland sites Oude Zanddijk and Welhoek.

It is interesting to note that the doves showed little interest in foraging in extensive areas of grassland, despite it being available in their home ranges**.** There are a few possible explanations for this:

1) Larger areas of grassland were available but were of low value as foraging sites – this could be caused by their location, the unsuitability of the vegetation structure, or the unsuitability of the seeds available.
2) Grassy road verges and dikes were widely available and provided better foraging habitat. This resulted in the doves actively targeting sites with grassy verges over larger areas of grassland.
3) The data collection or analysis method missed dove visits to extensive grassland sites. Given the number of points found along sites with grassy verges/dikes, it seems unlikely that whole land uses would be missed by the data collection method. However, the decision to exclude points within the turtle doves' territories (to eliminate singing/nesting/resting points – Section 5.1) may have influenced this.

Schuitsweg Grassland

This foraging site was part garden and part grassland (Section 5.3). The grassland had a number of tall trees on it and covered quite a small area, wedged between an arable field and several back gardens. Doves seemed to be foraging on the weed-rich grassland, along with chickens belonging to one of the houses.


Photos: Schuitsweg gardens/grassland

Oude Zanddijk Grassland Mosaic

This site was visited on multiple days in mid-August 2019. It is grazed by sheep, and the land parcel is split into two: the larger half being grassland dominated, and the other half grassland with an old, low intensity orchard. Oude Zanddijk contained a mosaic of different habitats, which might have been what interested the doves – paved tracks, an old shed, a ruined barn, 2 permanent ponds surrounded by trees, and a lot of overgrown hedges and tall trees. Henk's data indicates that he preferred to stay close to the hedges, trees and ponds.




Photos: Oude Zanddijk grassland site

Welhoek and Heggengebied Grassland, 2019/20

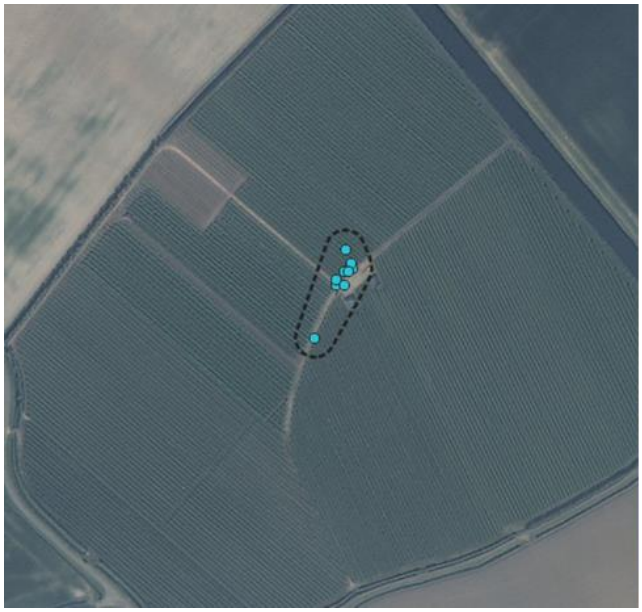
These foraging sites were located in large grassland areas grazed by cows (low intensity) and managed for nature. Both Heggengebied and Welhoek contain a lot of established scrub and overgrown hedgerow with larger trees protruding through it. Due to the presence of cows, the grass is kept low, there is plenty of bare ground, and there are many weeds (predominantly species not eaten by cows). There are also wet patches and ponds scattered through these nature areas, though no turtle doves were recorded here.

The Heggengebied site/s were generally smaller clusters of datapoints, often including roost points and focussed around a particular tree or hedge suggesting they were perhaps used more as resting/roosting sites than foraging sites. Welhoek was visited regularly by Bram in mid-June, 2020, and his datapoints are spread throughout the day and across the foraging site, suggesting he was indeed foraging here. What exactly drew him to this site is unclear from the distribution and timing of his datapoints at the site. Field visits revealed low, grazed grass, bare ground and (uneaten) weeds such as creeping and spear thistle (*Cirsium arvense and C. vulgare*), white clover (*Trifolium repens*) and hairy buttercup (*Ranunculous sardous*) – perhaps this was sufficient to attract him.

Photos: Welhoek grassland

5.5 Orchard

Of the 48 foraging sites identified, 13 contained orchard. While the doves datapoints indicate they might spend some time among or in the fruit trees, the majority of their points are concentrated on the edges, borders and tracks that run through the site. Pietersweg orchard (photos) illustrates this well. In the case of Ruigendijk - Korteweg Farm and Orchard, 2020 (Section 5.3), datapoints were clustered almost entirely around the yard and tracks (Figure 31). This suggests that Bram was more focussed on the weed-rich edges and grit tracks, rather than on the sprayed fruit trees. All orchard-dominated sites apart from one were visited earlier in the breeding season (May and June), suggesting that better foraging alternatives must have presented themselves from July onwards.



Photos: Pietersweg orchard

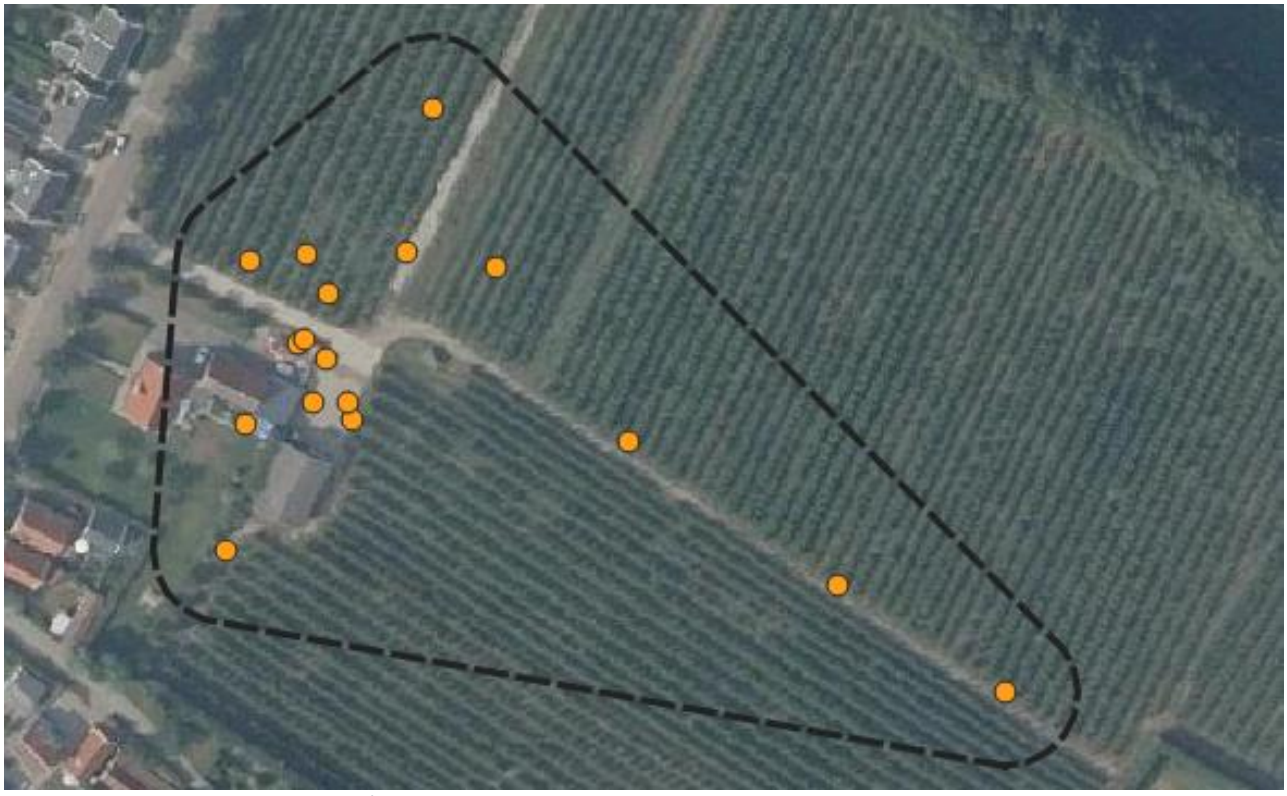


Figure 29: Ruigendijk-Korteweg farm/orchard

Nissestelle – Wilhoutspolder Orchard, 2020

This site was the only orchard-dominated foraging site visited later in the year. Bram used this location in the second week of September, and the timing of his visits was not the only difference. Bram appears to have utilised a large proportion of the whole orchard (photos) and showed surprisingly little interest in the tracks and larger patches of bare ground typically favoured by turtle doves earlier in the season. The most likely explanation for this is that Bram was finding sufficient food in the wheat stubble crop across the road and was using the orchard for resting rather than foraging. This theory is supported by a 3-day snapshot into Bram's movements during that week (Figure 32), which show Bram's datapoints alternating regularly between the orchard and the wheat stubble. In September, Bram's need to search for scattered weeds would be markedly less, as recently harvested grain fields would offer an easier, more convenient source of food. This is supported by the fact that other dove species were seen resting in the fruit trees and foraging on the wheat stubble. Additionally, the field where the wheat stubble was located was in a rather featureless landscape; the nearest trees for doves seeking shelter were on top of the dike (next to the road), or in the orchard.

Photos: Nissestelle – Wilhoutspolder orchard

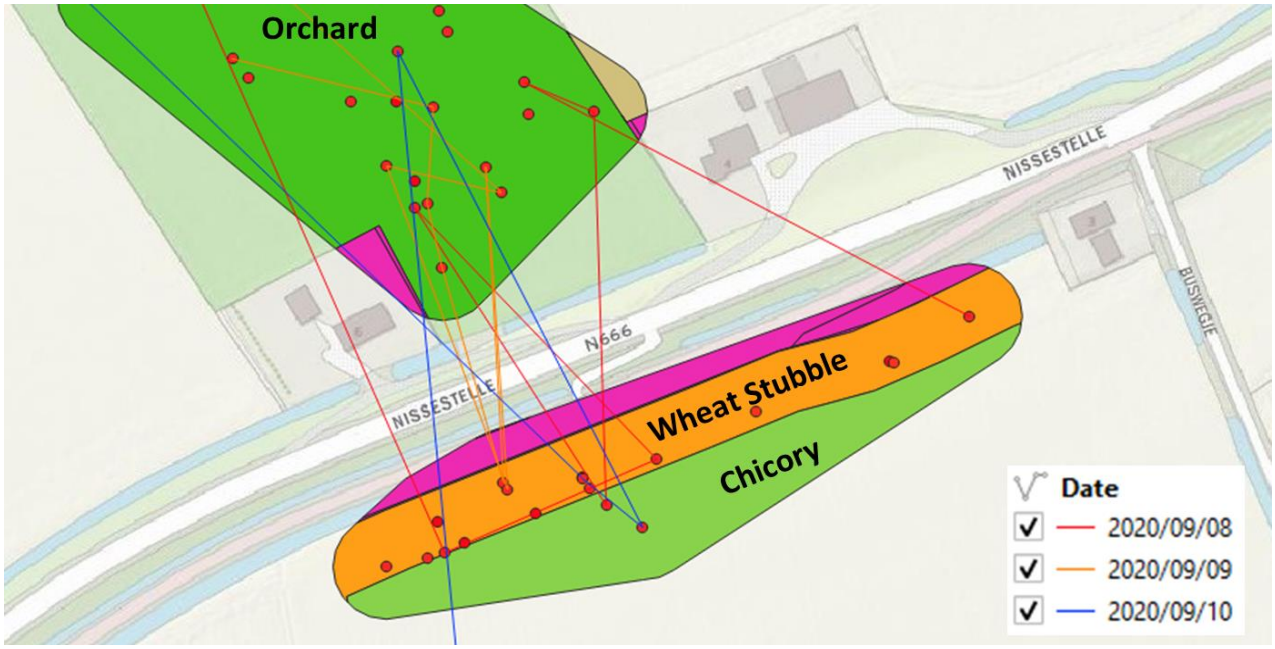


Figure 302: A 3-day snapshot into Bram's movements between Nissestelle – Wilhoutspolder orchard and Nissestelle crop field

5.6 Crops

While 34 foraging sites contained crops, closer inspection indicated that the turtle doves were not especially interested in this land use. At most of these sites, even where the crop dominated, doves stayed almost exclusively around field margins, yards, dirt tracks and roadside verges (Figure 33).

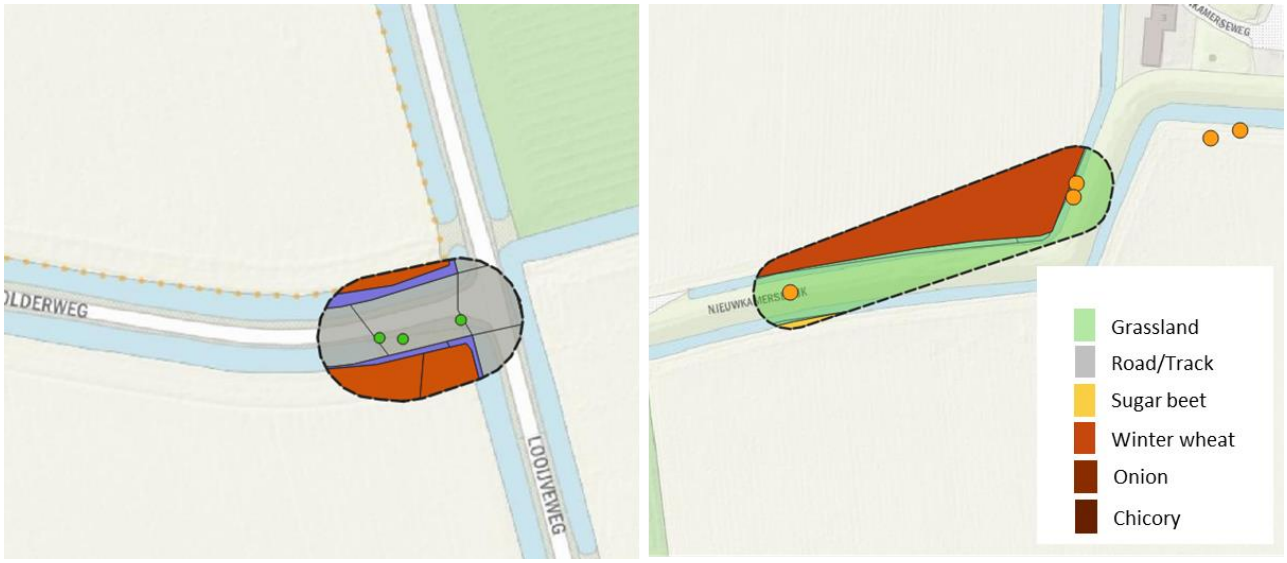


Figure 313: Foraging sites along Louisepolderweg/Looijveweg in 2019, and Nieuwkamersedijk in 2020

Behaviour of the project doves differed at only 6 sites, where doves showed real interest in the crop field itself. In 2019, 3 crop fields were identified – 1 blackcurrant, 1 mixed berry/nut bushes, and 1 blue poppyseed field. In 2020, 1 foraging site was a blue poppyseed field, and the other 2 were post-harvest wheat fields. What makes these sites even more interesting, is that they are all either minority crops (visited in July) or else post-harvest stubble (visited in August and September). These 6 foraging sites are considered in more detail in the rest of this section.

Brilletjesdijk: Blackcurrants, 2019

Rows of currant bushes contrast greatly with densely grown crops, such as wheat or maize, and allow for a lot of sparse vegetation along tracks and between rows. It is likely that spraying is restricted to the bases of bushes, allowing for more weed and grass growth along the paths. Site visits revealed sparse, weed-rich vegetation growing between the rows, and a high percentage of bare ground on the machinery tracks.

Photos: Brilletjesdijk blackcurrant field

Zuiderlandseweg: Mixed Berries and Nuts, 2019

This whole site had a very high percentage of bare ground, even between bushes, and obviously had a high intensity weed management regime. A range of different varieties were grown here – each variety grown for several rows after which the next variety began. All rows were grown parallel to the road. As with black current bushes, the less dense vegetation would make the field more appealing to the doves. However, contrary to the black current field, there were far fewer weeds growing at this site (photos). The turtle dove visits indicate a preference for a part of the field furthest from the adjacent roads and farms. It's unclear what might cause this – it's possible that a different weed-control regime was used in this corner, or that the doves found the loud dogs at the nearby farms off-putting.

Photos: Zuiderlandseweg mixed berry/nut field

Oude Zanddijk: Blue Poppyseed, 2019

Blue poppyseed was grown in just one field in the Zak van Zuid-Beveland in 2019. The site was first visited at the end of July, when the crop was ready for harvest and there were many weeds growing between the old plants (2/8/2019 photos). The crop was harvested within days, following which field visits to the stubble revealed it to be a 'hot spot' for turtle doves – presumably foraging on fallen seed or exposed weeds (20/8/2019 photos). Four turtle doves were seen during one visit, none of which were tagged. The site was ploughed on the 22nd of August, after which the foraging turtle doves immediately disappeared. This behaviour pattern reflects the observations of Dias and Fontoura (1996) and Dubois (2002) that the species feeds on cultivated crop seeds left on the ground post-harvest.

Photos: Oude Zanddijk poppyseed field, before harvest - 2/8/2019


Photos: Oude Zanddijk poppyseed field, after harvest - 20/8/2019

It's interesting to note the path taken by Henk when he visited the site before harvest: he followed the machinery tracks quite precisely (Figure 34). Although somewhat ironic, tracks made by the farmer during spraying provide an open vegetation structure with easy access to the ripe crop and weed undergrowth. The tracks themselves also contain many low growing weeds missed by the sprayer.

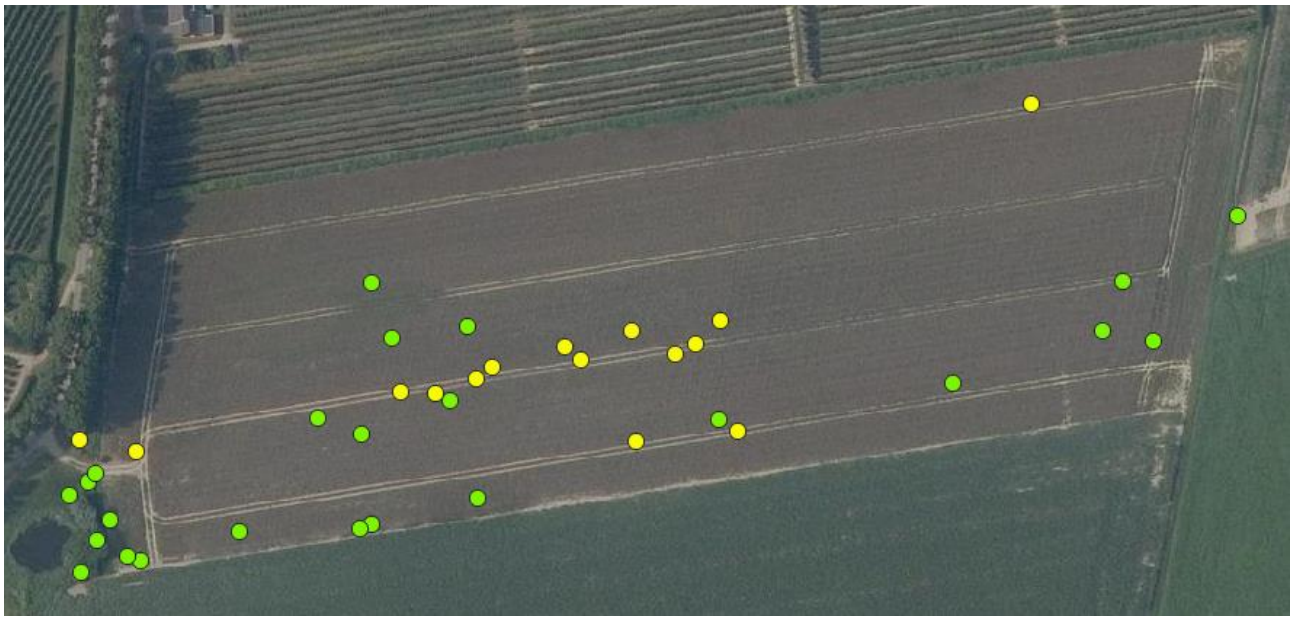


Figure 32: Oude Zanddijk poppyseed field – yellow points are pre-harvest, green points are post-harvest

Nieuwkamersedijk: Blue Poppyseed, 2020

In 2020, blue poppyseeds were grown in just 4 fields in the Zak van Zuid-Beveland making it, once again, a minority crop. The poppyseed field on Nieuwkamersedijk was the closest to Bram's territory, being just 1 km away, and it is the only poppyseed field he visited. Given that Bram flew almost 5 km from his territory to forage, the other 3 fields would have been within his reach. Perhaps he simply didn't find them –his apparent urge to stay close to his active nests could have driven him to forage closer to home than he otherwise would have done.

Only 3 datapoints were registered here before the field was harvested (Figure 35). Contrary to Henk in 2019, Bram did not appear to make use of the machinery tracks or bare ground to forage on the site prior to the harvest. Following the harvest, Bram visited almost daily between the 16th August and 4th September, using the whole site to forage. As in 2019, the blue poppyseed field was visited by more than just project doves: on one occasion 3 young and 2 adult turtle doves were observed in the field, excluding Bram. Interestingly, no turtle doves were seen on the barley or flax stubble in the adjacent fields, and Bram was never registered here.

Photos: Nieuwkamersedijk poppyseed field - before (left) and after (right) harvest

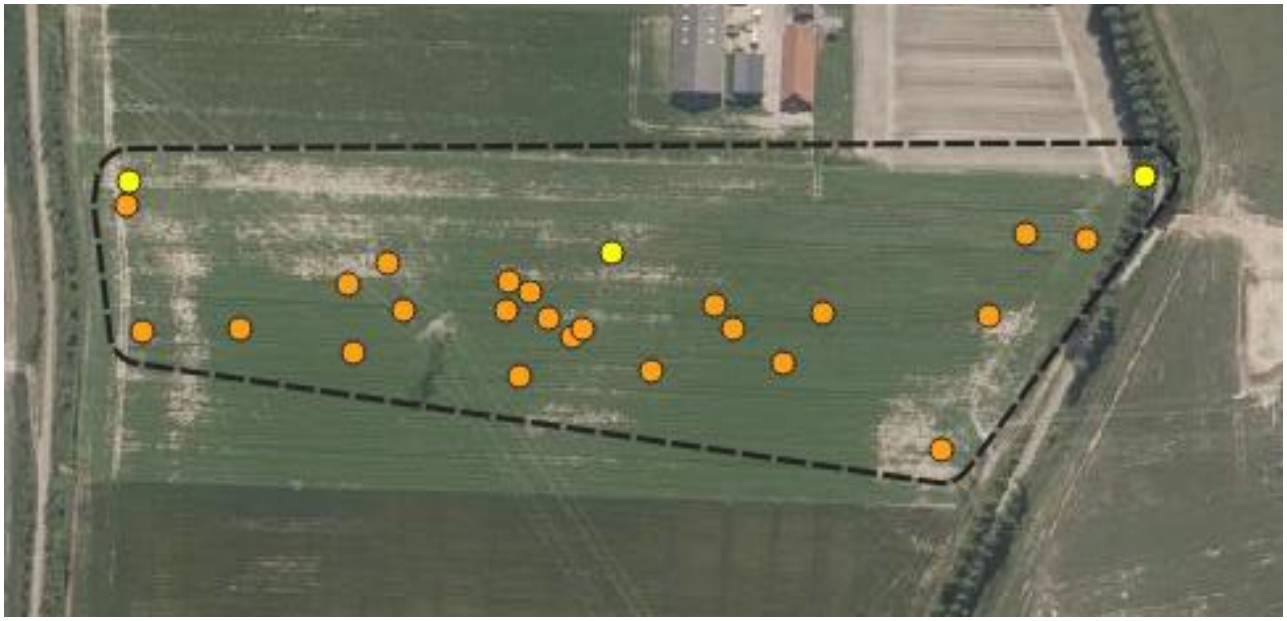


Figure 335: Nieuwkamersedijk poppyseed field – yellow points are pre-harvest, orange points are post-harvest

Nissestelle: Wheat stubble, 2020

A border of winter wheat surrounding a chicory field contained 2 foraging sites on opposite sides of the field. The sites were visited in the second week of September 2020, when the wheat border had been harvested but not ploughed. At both sites the doves were using the wheat border, rather than the chicory, with additional focus it seems on the especially bare strip between the 2 crops.

Photos: Nissestelle wheat stubble border

Oude Zanddijk: Onions, 2020

Apart from the 6 sites where turtle doves utilised the whole crop field, this unusual 7th site was identified along Oude Zandijk. While not overly common, onion fields were quite well spread throughout the study area. What made this site interesting is that Bram only used one corner of the field, showing no interest in the rest of the crop (Figure 36). The reason for this became apparent during site visits. Although the field was planted with onions, this small area had either missed sowing, or else been used too frequently as a turning point for farm machinery. This single corner was the most bare, weedy and unmanaged of the whole field. Not only were there no onions, but it seemed to have been missed by the sprayer and was rife with agricultural weeds such as redshank (*Persicaria maculosa*), white goosefoot (*Chenopoedium album*) and prostrate knotweed (*Polygonum aviculare*).

Figure 36: Oude Zanddijk onion field - additional site of interest

Summary of crop fields

As previously mentioned, all the crop fields where turtle doves had shown interest in the crop itself were either minority crops (visited in July) or else post-harvest stubble (visited in August and September). They were all characterised by a high percentage of bare ground, low and sparse vegetation (either low density bushes or harvested crops) and, in the case of post-harvest fields, high seed availability. These factors represent 'typically suitable' turtle dove foraging habitat in the literature, and would explain the dove's preference for these kinds of crop fields. While it's unclear why one stubble field was utilised and a neighbouring stubble field was not, the project doves did not visit any crop field containing densely planted and/or high growing crops.

5.7 Roads and Tracks

More than half of all foraging sites contained road or track and, when available, the turtle doves often stayed close to these hardened surfaces. Turtle doves were observed foraging on the road and wide grassy verges within the study area.

Apart from providing a potential source of grit for turtle doves, tracks/road edges aren't sprayed and are therefore comparatively rich in weeds. Being frequently driven on by vehicles, tracks (together with field margins, see Section 5.8) have the highest percentage of bare ground within land parcels. In the case of crops, tracks offer a sparser and more accessible vegetation structure compared to the rest of the field. Roads are also some of the most likely areas to be lined with trees or scrub in the Zak van Zuid-Beveland, which would provide shelter.

This land use is readily available, and while it might not provide optimal foraging habitat, it seems to provide sufficient foraging opportunities at that moment to interest the turtle doves. The photos below show 2 examples of foraging sites where the doves limited themselves to the tracks and roads.

Photos: Foraging site examples where roads/tracks were preferred

5.8 Verges and Field Borders

Verges and field borders, while not classed as a land use in themselves, proved significant enough to warrant their own section in this analysis. Doves showed great interest in field borders and wide roadside verges in general, regardless of whether this was in the form of marginal grassland (Section 5.4) or roads and tracks (Section 5.7). Field borders, as with tracks, are the most likely areas to contain heightened quantities of weed, and a sparser vegetation structure. They are also in closer proximity to other landscape features such as trees, scrub and hedges, which would provide shelter. Photos of 3 foraging sites preferred for their field borders are shown below.

Photos: Foraging site examples where field borders were preferred

Agri-environment Field Borders

It is important to note that despite the turtle doves' interest in field borders and verges, none of them were recorded at any borders planted through an agri-environment scheme. Many agri-environment borders were present within the home ranges of tagged doves, some just a few hundred metres away from turtle dove territories. While it wasn't possible to investigate which agri-environment borders were present in the area, or what their target wildlife was, field visits to some of the closest borders revealed them to be unsuitable foraging habitat for turtle doves, containing tall, densely planted flowering species. While some of the plants might provide interesting seed for turtle doves, the tall, unmanaged vegetation puts doves off as it doesn't allow visibility of the surroundings (risk of predators).

In contrast, previous research indicates that turtle doves prefer foraging sites that have an open and short vegetation structure, and contain a lot of bare ground (see contrasting photos below of the visited field borders in the Zak van Zuid-Beveland, and turtle dove habitat as recommended by Operation Turtle Dove). Based on the foraging site choices of the turtle doves followed during this research, these habitat recommendations appear to be accurate.


Photos: Agri-environment Scheme field border in the Zak van Zuid-Beveland, the Netherlands,2020


Photos: Suitable turtle dove habitat, as recommended by Operation Turtle Dove, England

5.9 Foraging within their Territory

The process used to identify foraging sites involved eliminating datapoints within each dove's territory, thereby avoiding the accidental classification of resting/singing points as foraging points. While this might mean that some foraging sites were ultimately missed, only project dove Bram was observed foraging within his territory. This was always at the same location: a small-holding/sheep farm near Nisse. While absent from the foraging site analysis, this is still a site of interest and is therefore covered here in more detail.

"Schaapskooi Schaap en Zo": Small holding and sheep farm, 2020

From mid-May turtle doves were observed foraging at the Schaapskooi alongside poultry and other wild birds (such as collared doves, jackdaws, chaffinches and sparrows). Turtle dove "Bram" was caught at this location at the end of May and, once tagged, continued to forage here (Figure 37).

Earlier in the breeding season Bram was observed and caught on camera foraging:

A) In the open poultry run
B) Around the farmyard
C) Along the track
D) In the small field

In addition to foraging, he was occasionally seen or heard in the scrub and trees along the surrounding dike, and in 2 particularly tall trees. These areas showed up as clusters of datapoints (indicated in yellow on Figure 37).

Given the proximity of Bram's observed foraging and singing locations, compared to his datapoints, it was not possible to ascertain which points were the results of foraging activity, and which were not. Even so, Bram used the site most intensely at the start of the season – over 70% of all his datapoints recorded in May were at this site. In September, just 5% of his datapoints were being recorded at the Schaapskooi (figure below).

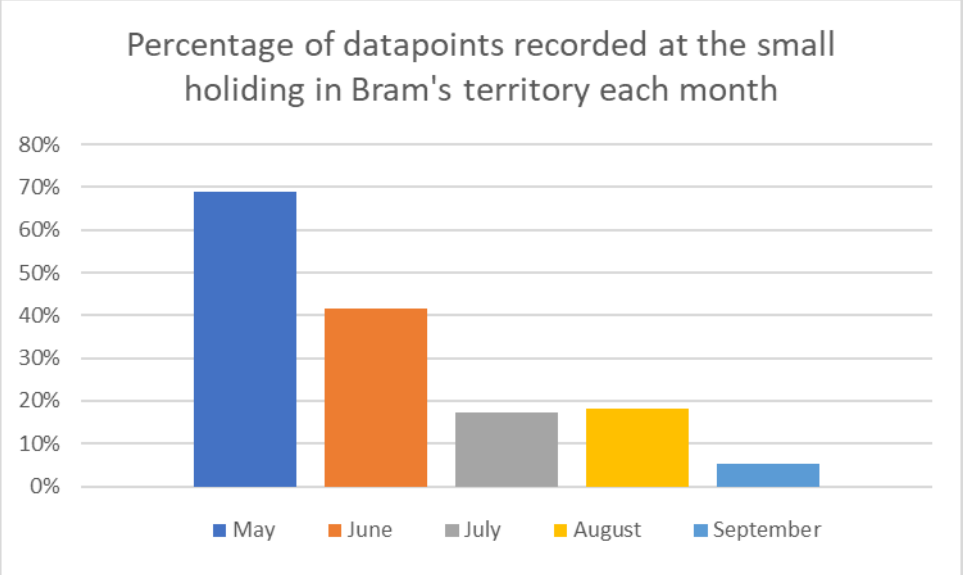


Figure 34: Schaapskooi small holding and sheep farm. Letters indicate foraging locations; clusters marked in yellow indicate locations where he was seen/heard in trees

6 Foraging Sites: Change over Time

In addition to similarities in the turtle doves foraging behaviour at each site, a shift in the land use was also seen during the course of the breeding season (Figures 38 and 39). The general progression of foraging site choice over time is summarised in Figure 39. Most notably was that farmyard sites were only visited in May and June, earlier in the breeding season, whereas crop fields were generally only visited from mid-July onwards. This was not entirely unexpected, since studies in the UK (Browne and Aebischer, 2003) found that turtle doves were feeding on spilt grain around farmyards and livestock feeding areas early in the season, and among cereal and rape stubbles in the latter half of the breeding season.

In early to mid-breeding season (June/July) the project doves visited mixed land use foraging sites more often than at the end of the season. Presumably these sites, comparatively rich in field margins, tracks and verges, offered ample feeding opportunities in the form of weeds.

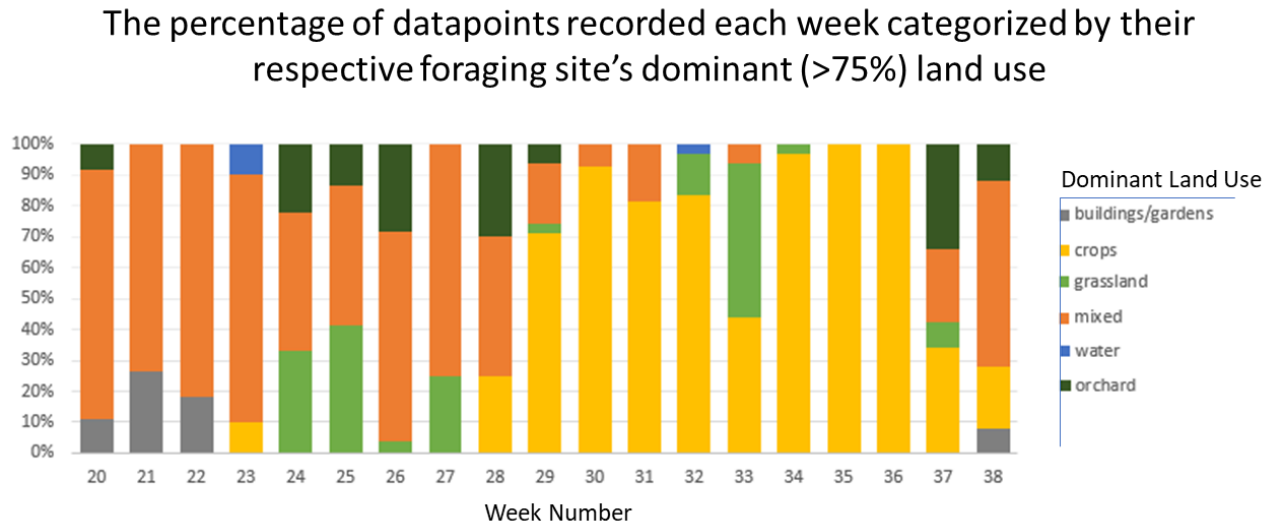


Figure 35: Percentage of datapoints recorded each week categorized according to foraging site land use

Regarding foraging sites where the doves showed interest in a crop, minority crops containing plenty of bare ground (such as blackcurrant) were visited in July, whereas crops like poppyseed and wheat were visited around/after harvest in August and September (Section 5.6). This is likely the result of a) bare and unsprayed ground being comparatively weed-rich to other fields, b) some crops, most notably poppyseed, being rich in weeds, and c) the high seed availability on ripe crop fields and stubble making foraging incredibly easy, and therefore very attractive, for the doves. It is logical that turtle doves would favour the easy foraging at newly harvested seed/grain fields, over weed-seeds available elsewhere that are more difficult to find or more sparsely distributed over the landscape.

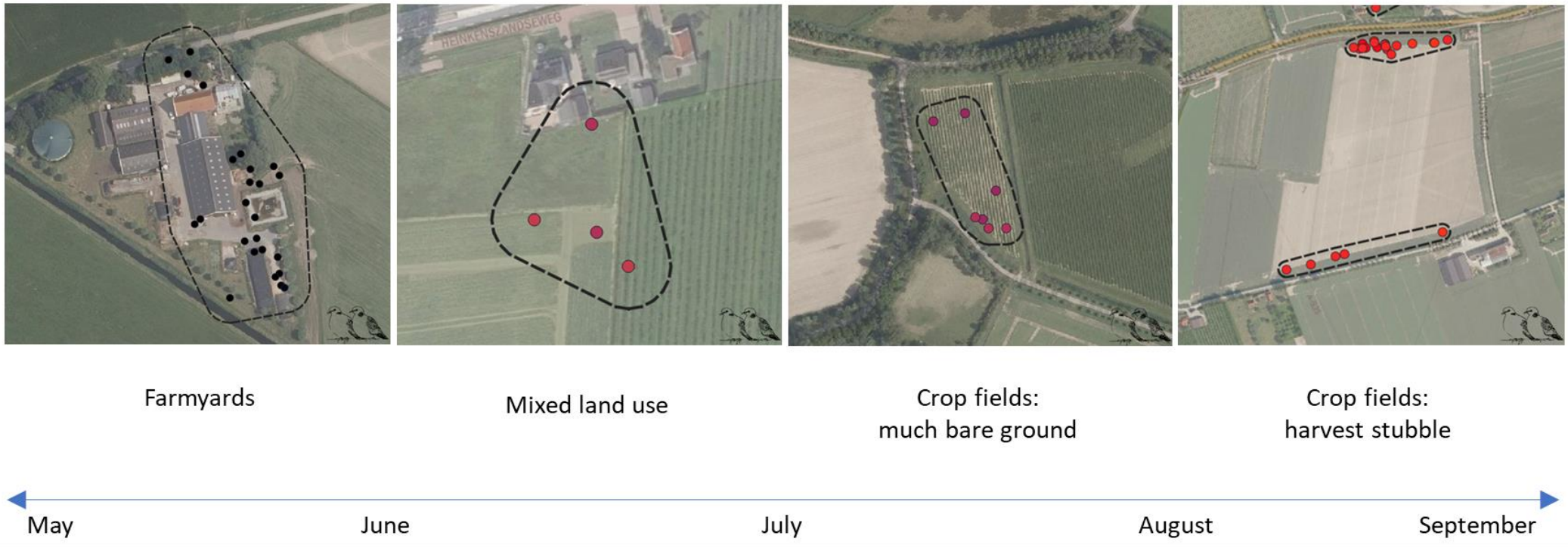


Figure 36: Trend in foraging site land use during the breeding season

7 Conclusion

What small scale movements did turtle doves make during the breeding season in the Zak van Zuid-Beveland?

The home ranges of the 5 tagged doves were calculated based on the data collected in breeding seasons 2019 and 2020. Omi and Linden had particularly restricted home ranges because they were not tracked for many days before they left the study area. Their home ranges were 90 ha and 3.9 ha respectively. Bram, Bernhard and Henk's home range sizes, of 1343 ha, 900 ha and 616 ha respectively, are large but come as no surprise following Browne and Aebischer's (2003) observation that home range sizes between doves vary greatly (0.3 ha to 1130 ha during their study).

During this research, turtle doves with an active territory were found to spend the bulk of their time in their territory – loitering and singing in trees around the perimeter. The bulk of these trees were not managed, had open canopies, and were often surrounded by overgrown scrub/hedge. Few datapoints were recorded far enough away from landscape features (trees, scrub/hedges, sometimes ponds) to determine whether doves were foraging in their territories. Additionally, no doves were observed foraging within their territory, with the exception of Bram. Bram's territory included a small holding where he was frequently observed and caught on camera foraging in the yard and poultry run, and in the small weed-rich meadow grazed by a few alpaca, sheep and horses.

The doves tagged during this research flew up to 5 km to visit foraging sites: Bernhard flew 5 km from his territory on the Bergweg to visit the DLF grass seed factory in Kapelle. Henk, on the other hand, flew shorter distances from his territory to forage – the furthest he was recorded from his territory was nearly 3 km. Bram flew up to 4.75 km to forage when he did not have an active nest. During egg incubation, Bram's foraging behaviour changed, with him staying much closer to his nest site (generally only flying up to 1 km away). Once his chicks had hatched and were becoming more independent, he started foraging further afield again. If this foraging behaviour change is typical for turtle doves with active nests, it is a strong argument for foraging habitat to be within close range of suitable nesting habitat – not only for newly fledged young, but also for incubating adults.

Having a nest significantly impacted Bram's daily movements, not only with regard to the distance he was willing to fly to forage. During incubation he took shifts with his partner to be on the nest – she would incubate the eggs at night, while Bram would take the daytime shift. Precise change-over times varied, with Bram coming onto the nest between 7:00 and 12:00, and leaving the nest again between 15:30 and 19:00. Bram appeared to forage both before and after sitting on the nest, and roosted in his territory but never in the same tree as his nest was.

Did the tagged turtle doves have a territory? If so, what habitat was it and what landscape features were present/absent?

Of the 5 tagged doves, only the 4 adult males had territories. Linden was a young male born in 2019, so was not expected to have a territory that year. The 4 identified territories ranged in size: Bernhard had the largest territory, at 11 ha, followed by Bram (7.8 ha), Omi (5.4 ha), and then Henk (3 ha). All 4 doves spent a lot of time in their respective territories, presumably staking their claim on the area and defending it.

The three turtle dove territories found in 2019 were located in small-scale landscapes, dominated by extensive grassland and containing a significant number of overgrown hedgerows, areas of scrub, taller trees, permanent ponds and many ditches. The grassland itself was predominantly managed for nature – either privately owned or owned by nature organisation Natuurmonumenten. Some areas of the grassland in Bernhard and Omi's territories were grazed more intensely by sheep, and a small portion of a land parcel in Henk's territory was managed by Natuurmonumenten as a small crop field.

Bram's territory prior to nesting (2020) had a similar land use composition to the 2019 territories, being dominated by grassland, and containing a lot of overgrown hedges and scrub, and a number of taller trees. Contrary to the other doves, Bram's territory also contained a few roads and tracks, and a small holding, which he used for foraging earlier in the breeding season. Bram's territory expanded when he started nesting in the scrub 500m away along a dike. Since the dike/scrub bordered an apple orchard and cropped field, Bram's resulting territory included crop and orchard land uses. While these land uses are considered part of his territory, his datapoints suggest he was far more interested in the landscape features and small holding.

Each territory had the highest concentrations of turtle dove activity around overgrown mixed-species hedgerows with taller trees growing through them. The doves' clear preference for these landscape elements reflects their habit of lingering and conducting territorial behaviour here (also observed by Browne et al, 2005). It is safe to conclude that these features are of great importance, not just as nesting habitat but also for territorial behaviour and resting.

What land uses did foraging turtle doves prefer?

During this research 48 foraging sites were identified. Almost half of these sites were made up of a combination of grassland, orchard, crops, roads/tracks, woodland, water and buildings/gardens. The other half were dominated by a particular land use (>75%). With so many foraging sites containing an array of different land uses, it appears that the tagged doves were specifically visiting areas where different habitats came together – the borders where one field or land use turns into another. These sites were also typically rich in a variety of landscape features such as trees, hedges and scrub. The combination of many and varied habitats and landscape features together in a relatively small area is reminiscent of the small-scale landscape known to be preferred by turtle doves – a landscape that used to be far more commonplace before the intensification of farming.

No foraging sites were located in villages/towns, indicating that the project turtle doves were not interested in feeding in back gardens alongside collared doves. The only exception to this was a mixed grassland/garden site on the edge of a village, where the grassland contained chickens and backed onto a small crop field. There were also no datapoints recorded in any agri-environment field borders, despite their availability in the study area. The dove's lack of interest in these is a strong indicator of their unsuitability as foraging sites – of those visited by researchers, this is most likely due to the high and dense vegetation structure. Additionally, no foraging sites were dominated by roads/tracks, woodland, fallow land or green manure crops.

Ultimately, the simple presence/absence of land uses at foraging sites revealed relatively little about the preferences of foraging turtle doves. The most interesting preferences and trends in behaviour were found when areas of high dove activity were identified on a site-by-site basis.

Where was turtle dove activity the most concentrated within foraging sites?

According to the literature, turtle doves are granivorous and feed primarily on the seed of wild, low-growing weeds and spilt crop seed. They are known to prefer short, sparse vegetation with a high percentage of bare ground. A closer look at the distribution of turtle dove datapoints within the identified foraging sites provided some insight as to where they are finding this kind of habitat.

At the majority of foraging sites turtle dove activity was concentrated around field borders, grass verges, roads, tracks and other areas of marginal habitat. This was even the case at foraging sites dominated by a particular land use. These places were all characterised by sparse vegetation, plenty of bare ground, and a heightened quantity of low-growing weeds compared to the surrounding area. In addition, they were often close to trees, scrub or hedges. This finding agreed with Browne and Aebischer (2005) who found that most doves feeding on cropped land tended to be concentrated around field margins.

Several sites were found though where turtle dove behaviour did not follow this pattern. This included a grass seed factory, 4 farms, and 6 crop fields. These sites could be loosely classed into two categories: sites where seed was made available through humans (silage/storage), and certain crop fields that were particularly seed-rich (crop and/or weed seed).

All the farms visited by tagged turtle doves had a slightly 'wilder' appearance –dove activity was most concentrated around open silage channels, manure piles, overgrown scrub, and unmaintained or unsprayed corners of farmyards. Three of the four farms were dairy farms (Section 5.3) that were using silage maize. This is probably not a coincidence: silage maize contains broken maize seed for turtle doves to forage on, whereas grass silage is usually cut well before the grass sets seed. The fourth farm was an orchard farmyard, where the track and farmyard were unsprayed and weed-rich.

At sites where the doves showed interest in a crop (Section 5.6), their activity was spread across the whole foraging site rather than being concentrated around field margins. All 6 of the sites identified were either minority crops which contained a lot of bare ground and weeds (such as blackcurrant and poppyseed), or they were post-harvest seed and grain fields where the stubble had been left (such as wheat and poppyseed). In the blackcurrant field, paths between the rows of bushes were unsprayed, weed-rich and had a low, sparse vegetation structure. Similarly, the machine tracks in the poppyseed fields were weed-rich and had a low, open vegetation. The harvested wheat fields didn't only present a suitable vegetation structure, but had the added advantage of fallen grain missed by the harvest. The core similarity found between the crop foraging sites was the type of habitat they offered: low, open, sparse vegetation and a good source of fallen grain or weed seed.

Are there any trends in foraging site choice over time?

Between the 5 tagged project doves, a shift in foraging site land use was apparent. Farmyards were only visited by the doves in May and June, after which their general preference seemed to be for foraging sites characterized by a variety of different land uses, field margins and tracks. Finally, from the end of July onwards, the tagged turtle doves focussed their attention on foraging sites dominated by the stubble of crops such as wheat and poppyseed. Without additional data, particularly regarding exactly what the doves were eating at each site, it's difficult to investigate this general trend in more detail. However, despite the limited sample size, several broader conclusions can be speculated.

Turtle doves are heavily impacted by human activity

Whether earlier in the breeding season on farmyards, or later in the breeding season at harvested grain/seed fields, turtle doves are heavily impacted by human activity. At the former, they depend on open silage channels and spilt grain, which will vary in its location and availability each year. At the latter, doves were observed using the tracks of farm machinery to forage around ripe grain/seed crops. After harvest, they are dependent on each landowner's decision to leave crop stubble several days/weeks before ploughing. All these factors are the result of decisions made by land owners and result in an unreliable source of food each year. A single year where few grain/seed fields are planted, or where few fields are left as stubble, could prove disastrous for turtle doves in the area – particularly those with a late nest of chicks to support.

Turtle doves forage at farmyards out of necessity

It seems that doves prefer non-built-up sites (fields, grassland etc.) to built-up sites (farmyards). Food is likely available at these farmyards throughout the year, yet the doves only visit them early in the breeding season, at a time when seed-producing weeds are probably limited.

The tagged turtle doves visited a combination of mixed land use sites, and crop sites with a high percentage of bare ground during the months June and July – a time of year when agricultural weeds would be ripening. It seems the doves were finding sufficient seed away from farmyards, when they concentrated their efforts on areas comparatively rich in weeds (i.e., unsprayed areas between crops/trees, tracks, field margins, derelict areas etc).

The intensity with which a site is used is a good indicator of its foraging value
Although the turtle doves used just a small number of farmyard and crop sites, these sites appear to have been used more intensely than other foraging sites. The doves seemed to rely quite heavily on farmyards earlier in the season, and the crop sites later in the season.

In the case of crop sites, while it's unclear whether doves were foraging on unharvested seed or on weeds that had grown up under the crop, in both cases, the tracks made by farm machinery and the stubble attracted the attention of the tagged doves. Additionally, the tagged doves were not the only (turtle) doves recorded at the poppyseed fields – up to 5 turtle doves were observed at any one time.

Where nesting locations are identified, what can be concluded regarding their nesting habitat requirements?

Turtle dove Bram had 2 nests in 2020 – the first in late June/early July, the second in early August. No nests were found in 2019. Contact with Bernhard and Omi ceased before they could establish a nest, Henk had just finished nesting, and Linden was Henk's offspring. Since he was only born in 2019, Linden was not expected to have a territory or nest in 2019. None of the doves tagged in 2019 returned to the study area in 2020.

Both nests in 2020 were found in overgrown hawthorn trees situated on a dike. A 40 m cross-section of the dike revealed 9 different habitats, located between the orchard and cropped field. These small-scale habitats included a dirt footpath, mown and unmown herb-rich grass verges, *Tilia* trees with open canopies, and overgrown scrub/hedge composed primarily of hawthorn, dog rose and willow. Such a variety of habitats in such a small area is reminiscent of a small-scale agricultural landscape, and is important for newly fledges doves that spend their time close to their nest (Dunn et al, 2016). Additionally, the nest site is just 500 m from a large pond, and a small holding (frequented by Bram) with easy access to seed.

Since Bram was the only project dove whose nests were identified, no generalised conclusion can be drawn. However, the importance of established scrub, and turtle dove preference for nesting in thorny bushes is well documented (e.g., Browne et al, 2004; Mason et al, 2000; Dunn et al, 2012).

8 Limitations and Discussion

A number of limitations were encountered during the course of this research, namely: a small sample size, the differing tracking periods between doves, technical limitations and analytical decisions.

Home Range and Territory

Defining exact boundaries for home ranges, territories and foraging sites was necessary to investigate the land use preferences of turtle doves. Although drawn using complex algorithms and professional knowledge, the boundaries created are fixed. In actual fact, all these boundaries are much more flexible and will have changed over time. The boundaries used for this analysis are only as good as the quantity and accuracy of the data collected, and the knowledge of the researcher. Given that territories and homes ranges were calculated based on doves that differed in both breeding status and time period, this presented some unique challenges for the calculation and accuracy of home ranges and territories.

Home ranges were calculated using the *a*-Loco algorithm, where the threshold of this function is determined by the researcher. Although a different threshold for each home range would have provided a better 'fit', a single threshold of 0.4 was used to make home ranges directly comparable. Threshold 0.4 was selected with the knowledge that it likely underestimates, rather than overestimates the home range – it was preferable to limit the amount of potentially uninteresting land included in the final home range.

Another point for consideration is that one would expect the home ranges to change over time, reflecting factors such as the bird's attachment to a territory, a nest, chicks or changes in food availability. In Bernhard's case (tracked from May to June), he had a newly established territory to defend and his choice of foraging sites will have been influenced by seed availability earlier in the breeding season. Henk however, tracked in July and August, was tagged after completing a successful breeding season: his home range will have reflected suitable foraging sites around harvest time, and his territory would need less defending. In actual fact, all 4 doves tracked in 2019 are likely to have home ranges *bigger* than what we were able to record. Bram, in 2020, was the only dove tracked through a whole (successful) breeding season, thereby providing a reasonably accurate overview of his home range, reflecting the different foraging sites he visited. It is noteworthy that his home range contracted significantly during the period of active egg incubation.

Regarding turtle dove territories, a 'best fit' boundary was drawn to use in this analysis. Although based on professional knowledge and the daily territory boundaries of each turtle dove's movements, it is still assigning a fixed boundary where none exists. Even with these limitations, striking similarities were still identified between the turtle dove territories. With only 1 dove (Bram) tracked for the whole breeding season, no trends/shifts in territory over time were observed. However, it was found that the initial territory Bram set up at the start of the breeding season was not where he chose to nest. The ultimate decision to include Bram's 2 nest sites in his territory for purposes of analysis, led to a notable change in land use composition in his territory, for example.

Foraging Sites

It was not possible to determine the turtle dove's exact behaviour at each location, so criteria were developed to try and isolate foraging points within the dataset. One of these was to exclude points recorded within, or close to, the dove's territory. Although turtle doves likely forage in and around their territory, these points were ultimately excluded to avoid over-estimating the number of foraging sites. By excluding them, however, there's a good chance of underestimating the foraging that occurs in extensive grassland – the primary land use within their territories.

Another obstacle was the occasional mis-classification of a roosting site. Most roost-only sites were excluded by the removal of each bird's territory and datapoints registered between midnight and 5am - for the large part doves roost in and around their territory. However, when a dove roosted elsewhere it fulfilled the criteria of a foraging site (i.e., a point cluster, outside the territory, containing points from more than 1 day, and/or a period of more than 2 hours). These sites were recognized by their location (mostly grassland sites with points concentrated on a suitable tree), the timing of points (a single late night and early morning, with no repeat visits), and the presence of 1 or more night-

time points in the cluster. While turtle doves have been recorded foraging as early as 5am, the combination of these factors led to the declassification of 10 sites.

These roosting sites were not the only ones to be misclassified. While some of these were relatively easy to identify, others were more ambiguous and therefore remained in the analysis. Furthermore, the activity of tagged turtle doves at a further 4 sites called into question their classification as 'foraging sites'. While these were also included in the analysis, the movement of doves strongly suggested these sites were in fact 3 resting sites (adjacent to intensely used foraging sites), and 1 site used by Bram in September for roosting and loitering after he had abandoned his territory.

Even with a small sample size, the similarities between foraging sites were impressive. Additionally, comparing site choice to the time of year indicated a seasonal progression that is documented in literature (Browne et al, 2003). Where from data in 2019 hinted a shift in foraging site choice over time, the addition of Bram's 2020 dataset only served to reinforce the idea.

Technical Limitations

As previously discussed in Chapter 3, how well the battery is able to recharge relies on a number of independent and unpredictable factors: tags needed to be tried and tested in the field until a suitable recording interval could be found. Data collection intervals subsequently range from 3 minutes to 2 hours, and there are several data gaps where the solar panel was unable to recharge the battery enough for the next coordinate reading. The larger data collection intervals and data gaps, increase the chance of doves' locations being 'missed' by the trackers – this created a lower accuracy in the home range and territory calculations and a lowered chance of identifying all foraging sites. A smaller interval between recorded locations would have resulted in more datapoints, thereby increasing the accuracy of territory and home range boundaries and foraging site identification.

Tag accuracy is another technical limitation. Most points have a 15 m accuracy, and clusters of points can indicate areas that interested the doves. However, identifying precisely which feature was interesting the doves was almost impossible. Especially when landscape features are close together (for example, a roadside verge, the road or the tree next to it). Therefore, the analysis relied more on patterns and trends in point distribution between several sites in order to determine which features were most likely to be interesting the doves.

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Appendices

Appendix 1: International Objectives Addressed by this Research

(Taken from the International Species Action Plan for the Turtle Dove, May 2018)

FRAMEWORK FOR ACTION

Goal

To restore the European turtle-dove (*Streptopelia turtur*) to a favourable population status so it can be safely removed from the threatened categories of the IUCN Red List.

High Level Objective

To halt the population decline of the European turtle-dove throughout most of its range, preparing the way for an increase in population sizes within each flyway during the period of the next version of the Action Plan (2028 to 2038).

Results and actions

IMPORTANT NOTE: with such a wide-ranging species as the European turtle-dove, due to local or regional specific circumstances (for instance the average size of agricultural holdings, local climatic and bio-geographic circumstances, legislation adopted etc), not all measures will be applicable to all Member States. Discussion on the threat level assessment and associated limitations can be found in Annex 2: PROBLEM ANALYSIS on page 88.

In the actions below, *recent range* refers to areas where the species is no longer found, but was present at some time within the 30 years prior to 2018 (i.e., since 1988).

Threat level assessment

Critical - causing or likely to cause very rapid declines and/or extinction
High - causing or likely to cause rapid decline leading to depletion
Medium - causing or likely to cause relatively slow, but significant, declines
Low - causing or likely to cause fluctuations or minimal change
Local - causing or likely to cause negligible declines in small parts of the population
Unknown - likely to affect the species, but extent unknown

Action priority

Essential
High
Medium
Low

Action timescale

Immediate - to commence within the next year
Short - to commence within the next 3 years
Medium - to commence within the next 5 years
Long - to commence within the next 10 years
Ongoing - currently implemented and should continue

Completed - completed during preparation of the Action Plan

Objective 7: Knowledge gaps are filled, critically in areas that help increase the understanding of factors acting on the wintering grounds south of the Sahara, where information is very limited

Result	Action and scope	Priority	Timescale	Organisations responsible	Inputs required
7.1 More complete knowledge of turtle-dove movements throughout the yearly cycle by 2020.	Action 7.1.1 **Undertake studies to determine migration routes and key stopover/bottleneck areas** in Western Europe, Eastern Europe and Central Asia. Applicable to: all western Europe and African Range States.	Medium (W) High (E/C)	Short	**CONSERVATION NGOs, ACADEMIC INSTITUTIONS / RESEARCH AGENCIES**, hunting federations / associations, local hunting groups, national authorities (wildlife management)	Ringing and tagging studies, EURING, common bird monitoring, genetic studies.
7.4 Greater understanding of the key components needed in a turtle-dove's breeding and wintering habitat by 2020.	Action 7.4.1 **Improve knowledge of turtle-dove habitat selection and dietary needs**, and undertake regional comparisons of population changes to changes in the agricultural landscape. Applicable to: all Range States.	Essential	Short	**CONSERVATION NGOs, ACADEMIC INSTITUTIONS / RESEARCH AGENCIES**, hunting federations / associations, local hunting groups, national authorities (wildlife management)	Existing successful prescriptions for turtle-doves, research papers, hunting bag samples.
	Action 7.4.2 **Undertake tracking studies** to determine small-scale movements of birds within their breeding area in different habitats (forest, agricultural landscapes), and assess how they link with breeding productivity. Applicable to: all Range States.	High	Short	**CONSERVATION NGOs, ACADEMIC INSTITUTIONS / RESEARCH AGENCIES**, hunting federations / associations, local hunting groups, national authorities (wildlife management)	Actions 7.1.1-7.1.4 Action 7.4.1

Appendix 2: Bird Ringing Forms and Photos

Ringing Form

Project Turtle Doves in a Changed Landscape
Location Bergweg
Date 13/5/2019 **Time** 10:30

Species	European turtle dove
Name	Bernhard
Ring Number	2518152
Tag Type	GPS
Tag Make	Milsar Nano-3
Tag Serial Number	12BC041E
Tag ID Number	998003
Sex	Male
Age	>1 calendar year
Wing Length (mm)	183mm
Weight (g)	146.68g
Tarsus (mm)	24.5;25.0;24.2
Tarsus - Toe	48mm
Bill (tip to feathers)	16mm
Head - Bill	45.4mm
Bill Width (front of nostrils)	3.9mm
Bill Depth (at chin feathers)	4.3mm
Fat – if possible (0-5 scale)	1
Cloaca	0
Brood Patch	Bare
Body Moult	0 feathers
Moult Score	-
Handicaps	-
Notes	-

Ringing Form

Project Turtle Doves in a Changed Landscape
Location Bergweg
Date 14/5/2019 **Time** 11:00

Species	European turtle dove
Name	Omi
Ring Number	2518153
Tag Type	GPS
Tag Make	Milsar Nano-3
Tag Serial Number	10BC041E
Tag ID Number	998002
Sex	Male
Age	>1 calendar year
Wing Length (mm)	183.5 mm
Weight (g)	165.00 g
Tarsus (mm)	25.1 mm
Tarsus - Toe	51.0 mm
Bill (tip to skull feathers)	16.0 mm
Head - Bill	51.9 mm
Bill Width (front of nostrils)	5.0 mm
Bill Depth (at chin feathers)	4.85 mm
Fat – if possible (0-5 scale)	1
Cloaca	0
Brood Patch	1-2 bare and red
Body Moult	0 feathers
Moult Score	-
Handicaps	-
Notes	-

Ringing Form

Project Turtle Doves in a Changed Landscape
Location Heggengebied
Date 1/7/2019 **Time** 09:00

Species	European turtle dove
Name	Henk
Ring Number	2518154
Tag Type	GPS
Tag Make	Milsar Nano-3
Tag Serial Number	15BC041E
Tag ID Number	998004
Sex	Male
Age	>1 calendar year
Wing Length (mm)	185 mm
Weight (g)	166.50 g
Tarsus (mm)	24.1; 24.2 mm
Tarsus - Toe	54 mm
Bill (tip to skull feathers)	18.6; 16.5; 16.4 mm
Head - Bill	45.6; 44.7; 45.5 mm
Bill Width (front of nostrils)	4.7; 4.3 mm
Bill Depth (at chin feathers)	4.4; 4.4 mm
Fat – if possible (0-5 scale)	1
Cloaca	0
Brood Patch	Bare and red
Body Moult	>20 feathers
Moult Score	Secondaries only
Handicaps	-
Notes	1 feather in pin lost – presumably due to the net Captured with young (Linden, ring number: 2518155)

Ringing Form

Project Turtle Doves in a Changed Landscape
Location Heggengebied
Date 1/7/2019 **Time** 09:30

Species	European turtle dove
Name	Linden
Ring Number	2518155
Tag Type	GPS
Tag Make	Milsar Nano-3
Tag Serial Number	13BC041E
Tag ID Number	998001
Sex	Male
Age	1 calendar year
Wing Length (mm)	172.5 mm
Weight (g)	118.20 g
Tarsus (mm)	24.0; 23.8; 23.55 mm
Tarsus - Toe	49 mm
Bill (tip to skull feathers)	16.4; 16.35 mm
Head - Bill	45.3; 45.6 mm
Bill Width (front of nostrils)	5.1; 4.7; 4.65 mm
Bill Depth (at chin feathers)	4.0; 3.8 mm
Fat – if possible (0-5 scale)	0
Cloaca	-
Brood Patch	-
Body Moult	>20 feathers
Moult Score	-
Handicaps	-
Notes	Captured with Henk (ring number: 2518154)

Ringing Form

Project Turtle Doves in a Changed Landscape
Location Schaapskooi Schaap en Zo, Nisse
Date 30/5/2020 **Time** 08:25

Species	European turtle dove
Name	Bram
Ring Number	2518156
Tag Type	GPS
Tag Make	Milsar Nano-3
Tag Serial Number	15BC041E
Tag ID Number	998004
Sex	Male
Age	>1 calendar year
Wing Length (mm)	183 mm
Weight (g)	166.40 g
Tarsus (mm)	24.5 mm
Tarsus - Toe	52 mm
Bill (tip to skull feathers)	17.6 mm
Head - Bill	47.2 mm
Bill Width (front of nostrils)	4.55 mm
Bill Depth (at chin feathers)	5.0 mm
Fat – if possible (0-5 scale)	1
Cloaca	Small, not obvious
Brood Patch	Bare tummy, normal colour, unwrinkled
Body Moult	<20 feathers
Moult Score	-
Handicaps	-
Notes	

Appendix 3: Henk's Death

Unfortunately, Henk died around the 26th August 2019 – more than 8 weeks after being tagged in the Heggengebied with his young (Linden).

Photo: Henk (left) with Linden the day he was tagged

His last weeks were spent predominantly at the blue poppyseed field on Oude Zanddijk, fattening up in preparation for his annual migration. He was seen in the field behaving unusually 'quiet' on 23rd August: walking on the ploughed field, but not foraging. He did not fly to the nearest trees when disturbed and was clearly unwell.

The initial question was whether this is due to disease or to the harness/tag. His walking movements did not seem difficult or restricted in any way and, while he was not flying to the nearest trees, he was observed with binoculars flying a short distance. His wing beats were strong and the movement appeared normal and unhindered. This suggests the problem was not so much to do with a poorly fitting or painful harness/tag – if this had been the case then Henk would have likely had difficulty moving or had an abnormal flight. He did not gain much height though, only flying a short way before settling back down on the field, which could suggest a lack of energy. His tag recording frequency was increased and the site visited daily, in the hopes of catching and examining Henk, but his body was found on the 27th August, well hidden under a copse of trees surrounding the pond.

Unfortunately, his body was already in a state of decomposition when it was found, making it impossible to examine properly: virtually all internal organs were missing and the feathers fell out as soon as the body was touched. The weather was unusually hot and dry, perhaps speeding up decomposition. While no characteristic Trichomoniasis lesions were visible inside the mouth, it was noted that several grains appeared caught in his beak and throat – these were removed and put into sample bottles. Several swabs were also taken from (what remained of) his crop and throat in the hopes that a viable sample might be retrieved. These have been sent off, together with the grains, to Yvonne Schumm at the Justus Liebig University of Giessen, Germany, for Trichomoniasis testing (results pending).

Henk's movements became noticeably restricted from the 24th of August onwards. Consequently, data collected by Henk's tag during his last days has been discounted from this research analysis. Henk's data suggests a gradual shift away from his territory in the Heggengebied, in line with what might be expected from a turtle dove preparing to leave his European breeding grounds. However, we cannot rule out that this shift was caused by his ill health.

Appendix 4: Was Linden Henk's offspring?

Henk was captured together with Linden; a young male dove on 1st July 2019. This begged the immediate question: are they related? Upon their release the two males kept close company until contact with Linden ceased 5 days later (Figure below). It is likely that Henk had finished a successful breeding season by July and that Linden was his recently fledged offspring. Linden may have left the Heggengebied due to natural dispersal, or he might have been predated.

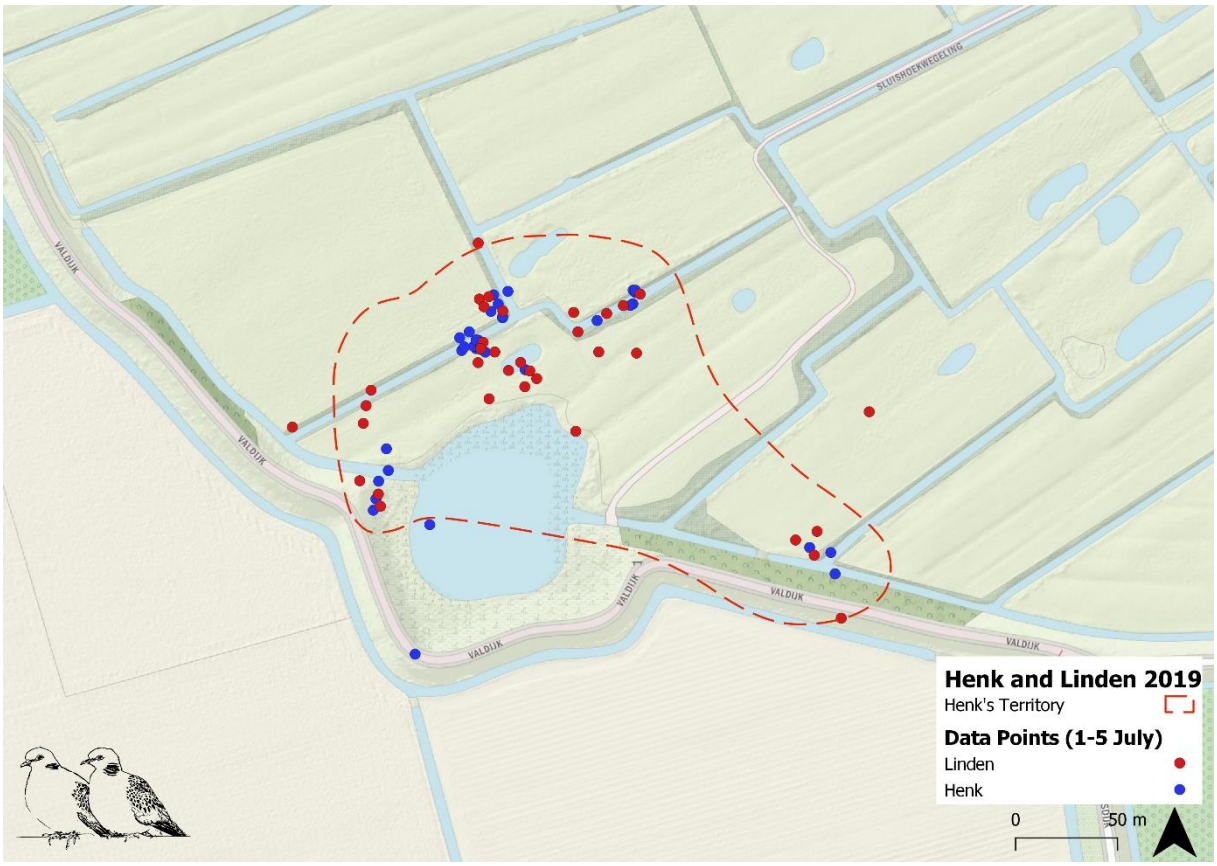
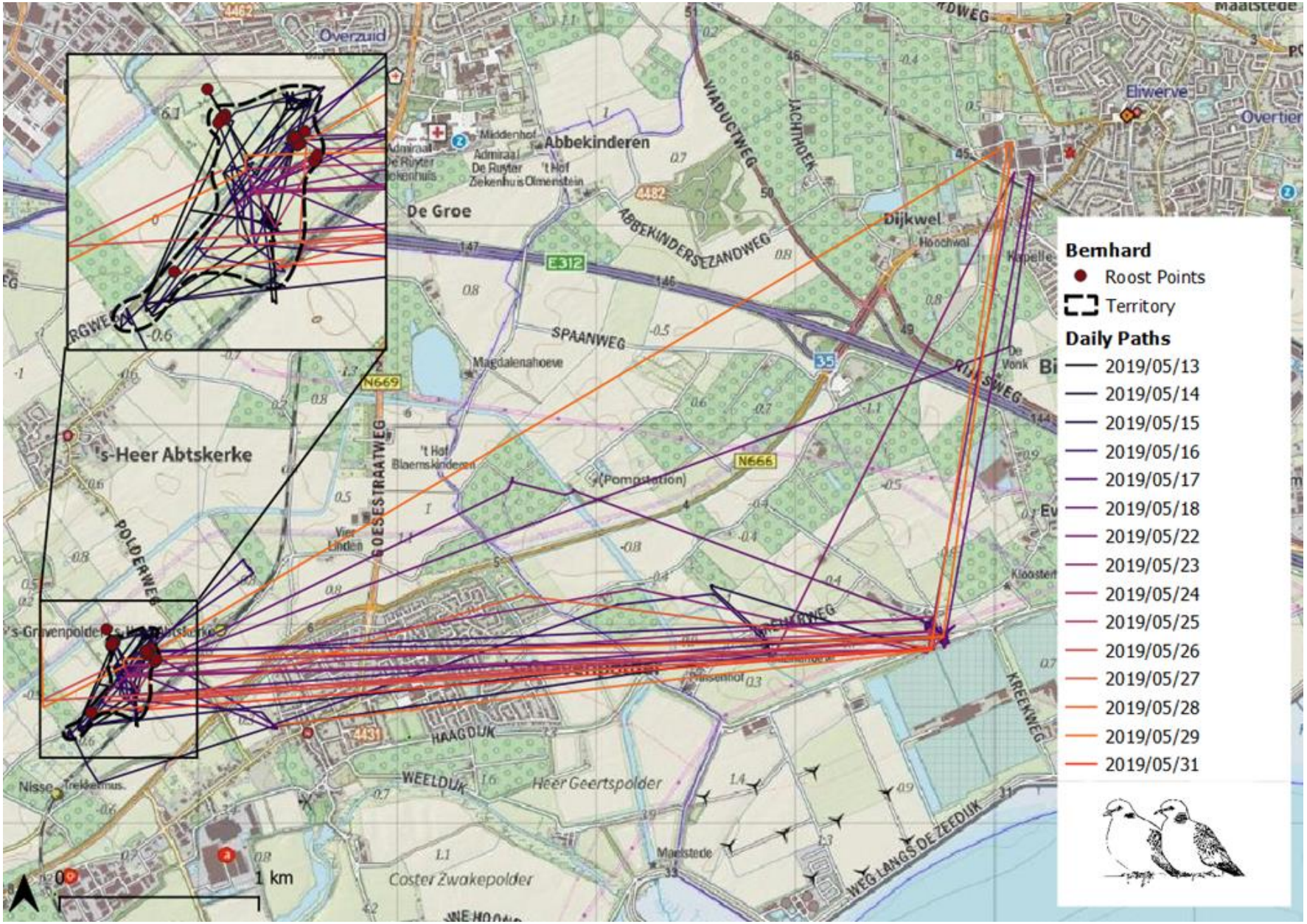
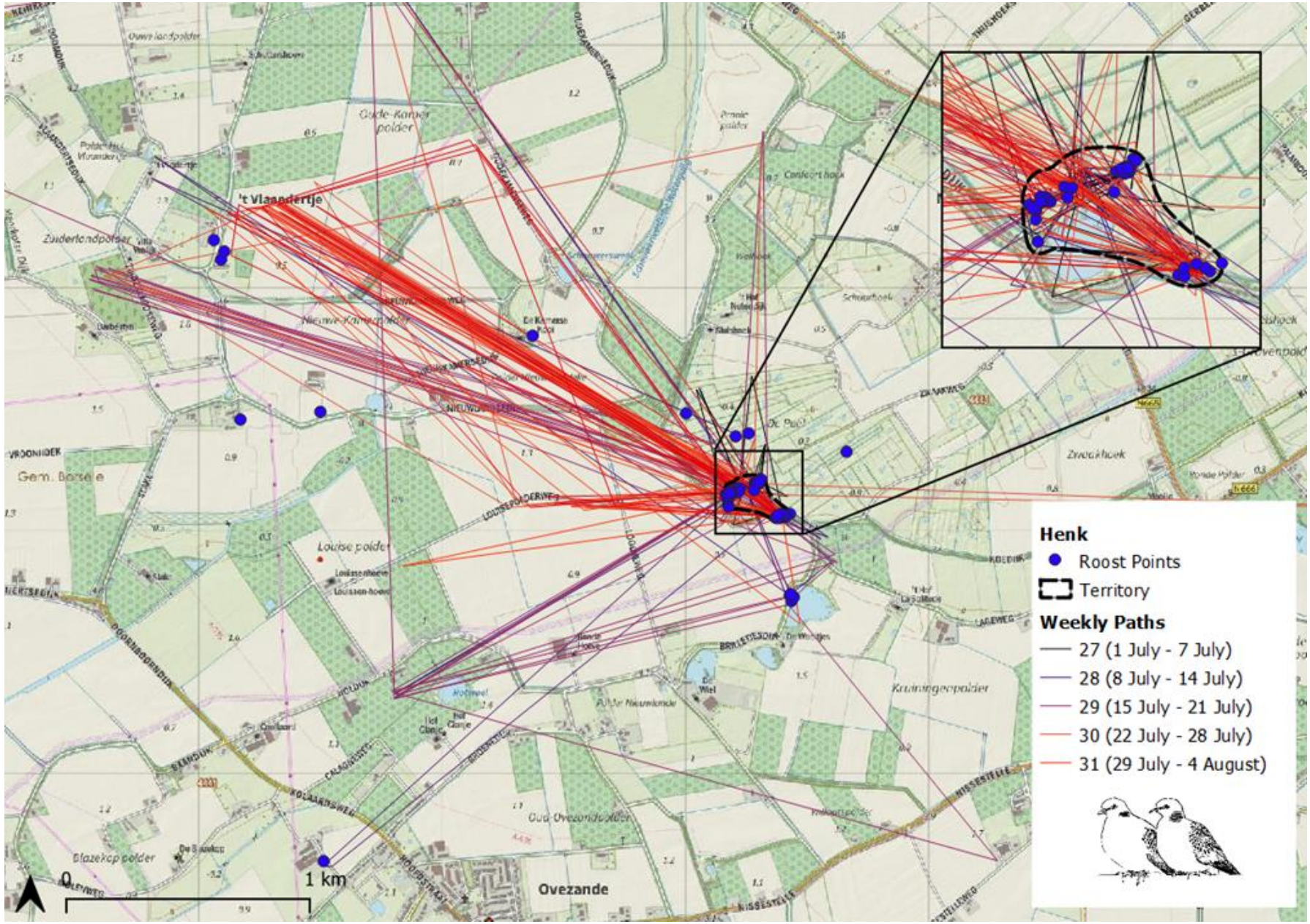


Figure: Henk and Linden's datapoints (1st to 5th July 2019)

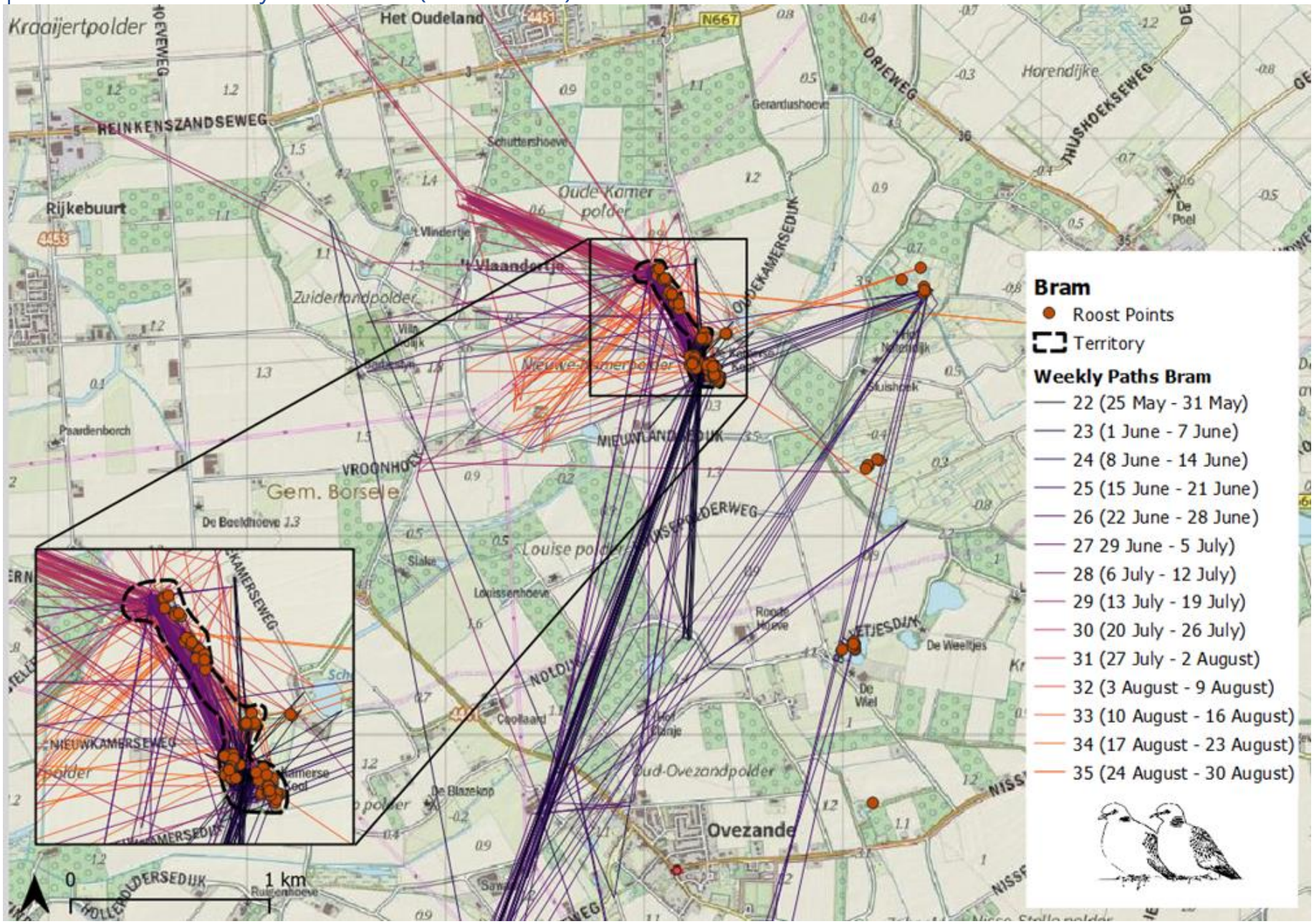
Appendix 5: Bernhard's daily movements



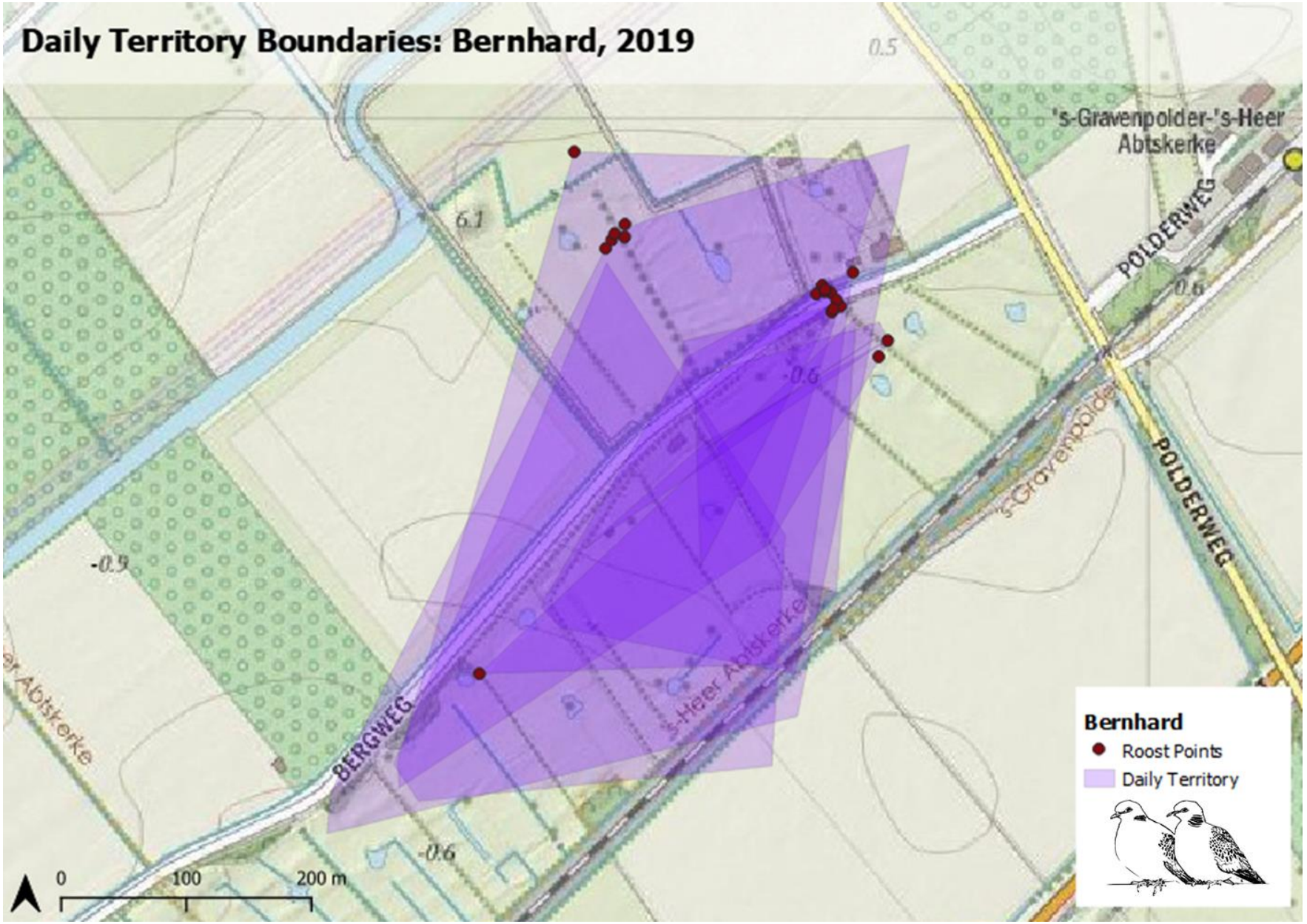
Appendix 6: Henk's weekly movements (weeks 27-31)



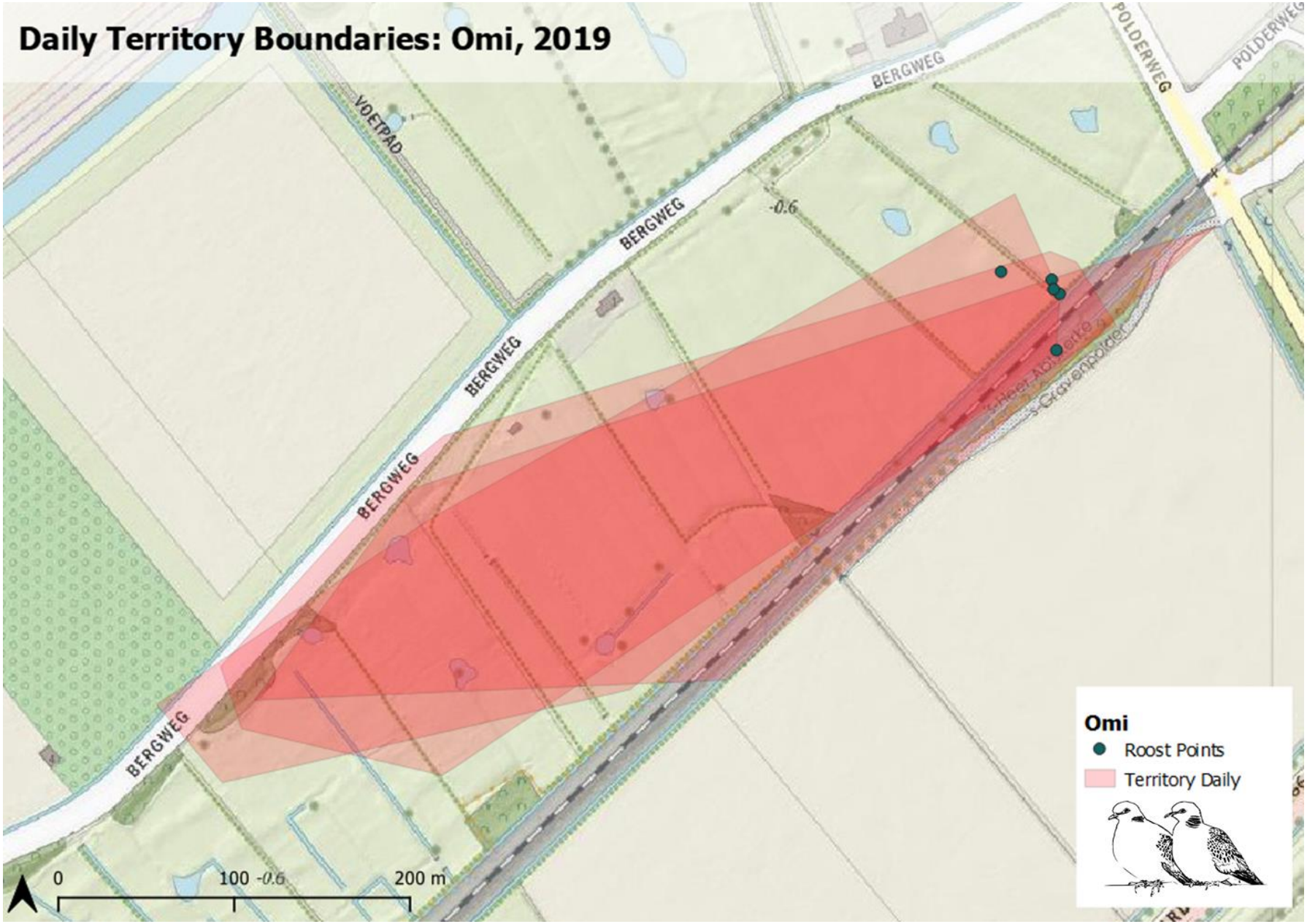
Appendix 7: Bram's weekly movements (weeks 27-32)



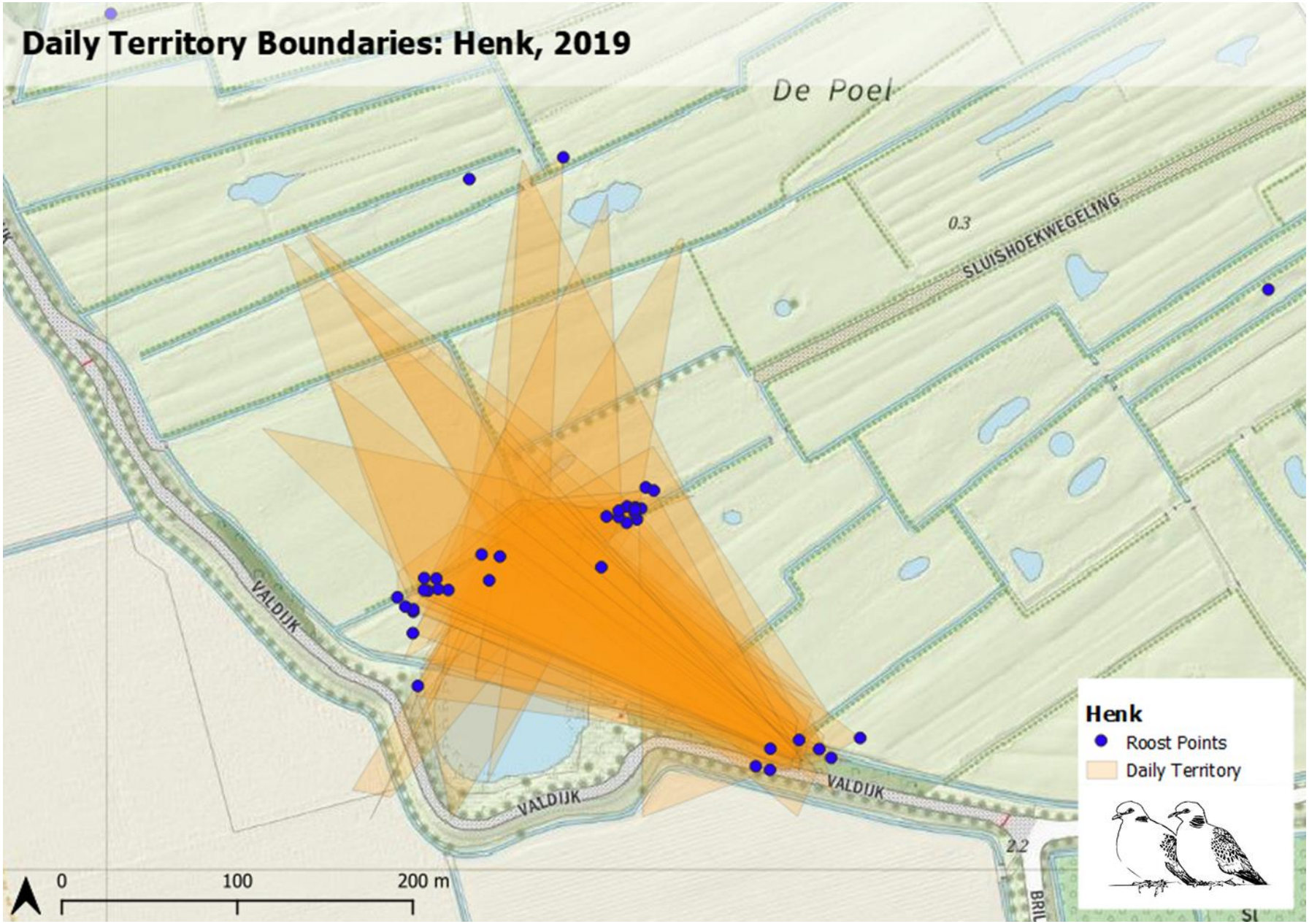
Appendix 8: Daily territory boundaries of Bernhard



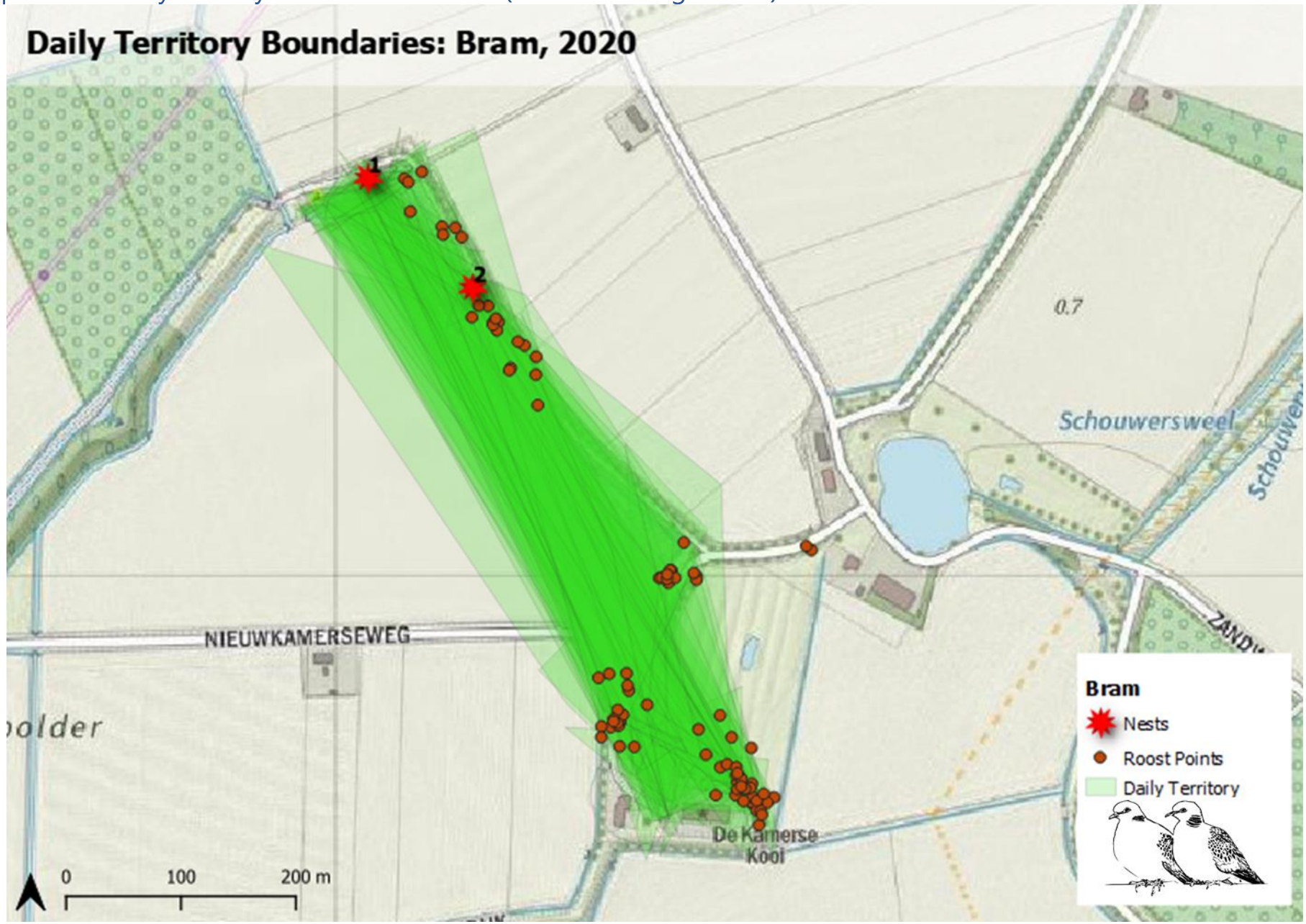
Appendix 9: Daily territory boundaries of Omi



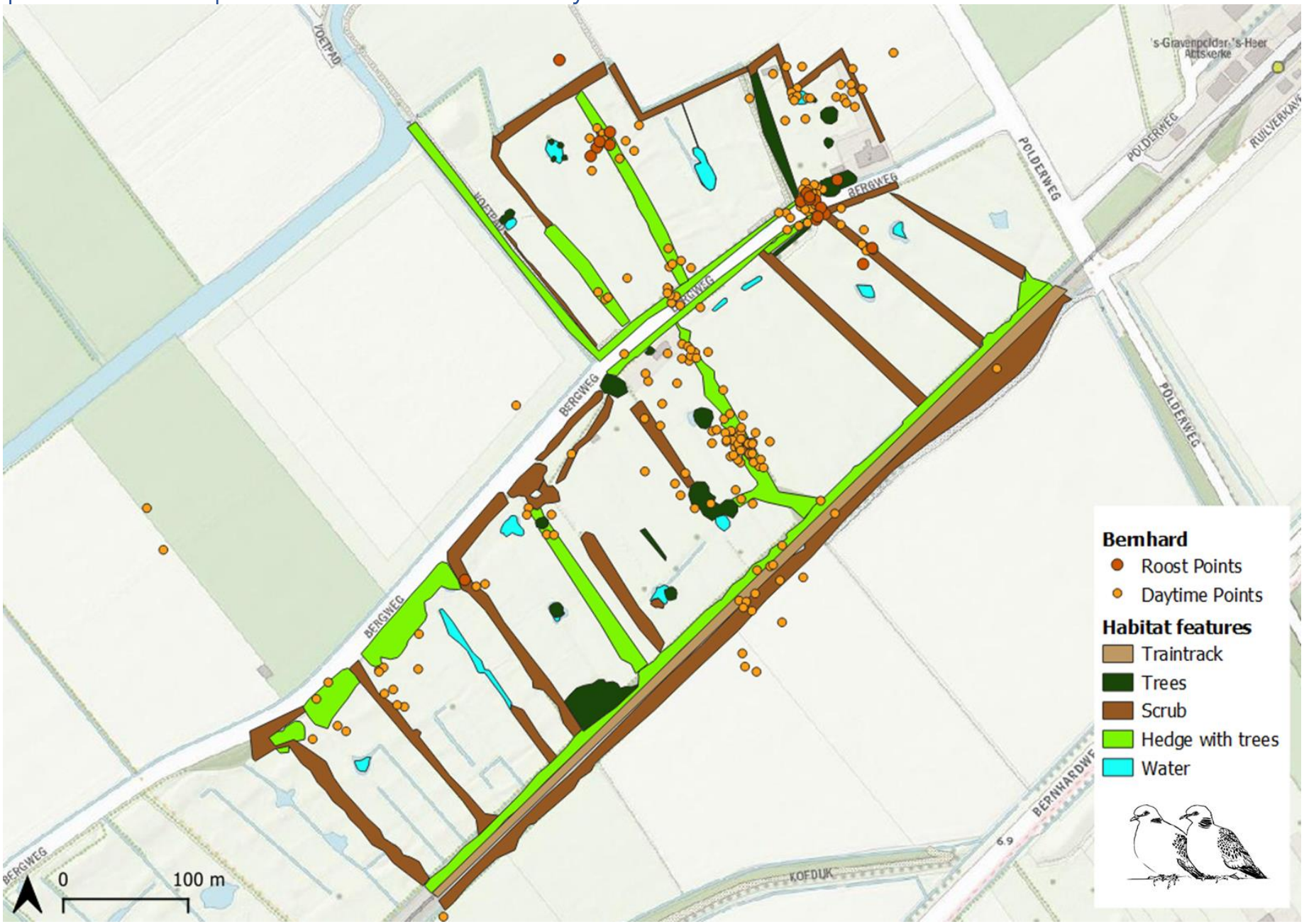
Appendix 10: Daily territory boundaries of Henk



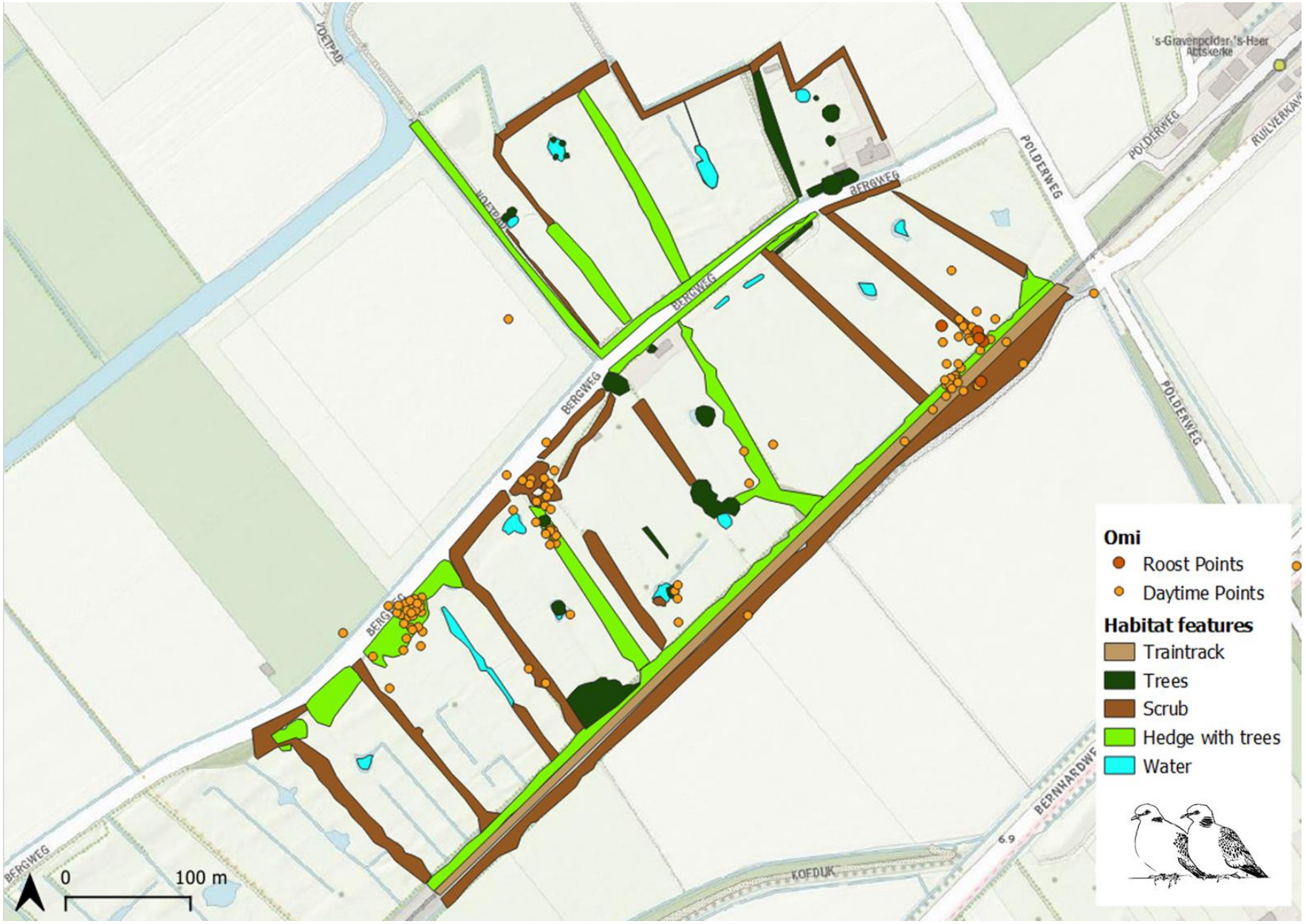
Appendix 11: Daily territory boundaries of Bram (whole breeding season)



Appendix 12: Landscape features in Bernhard's territory

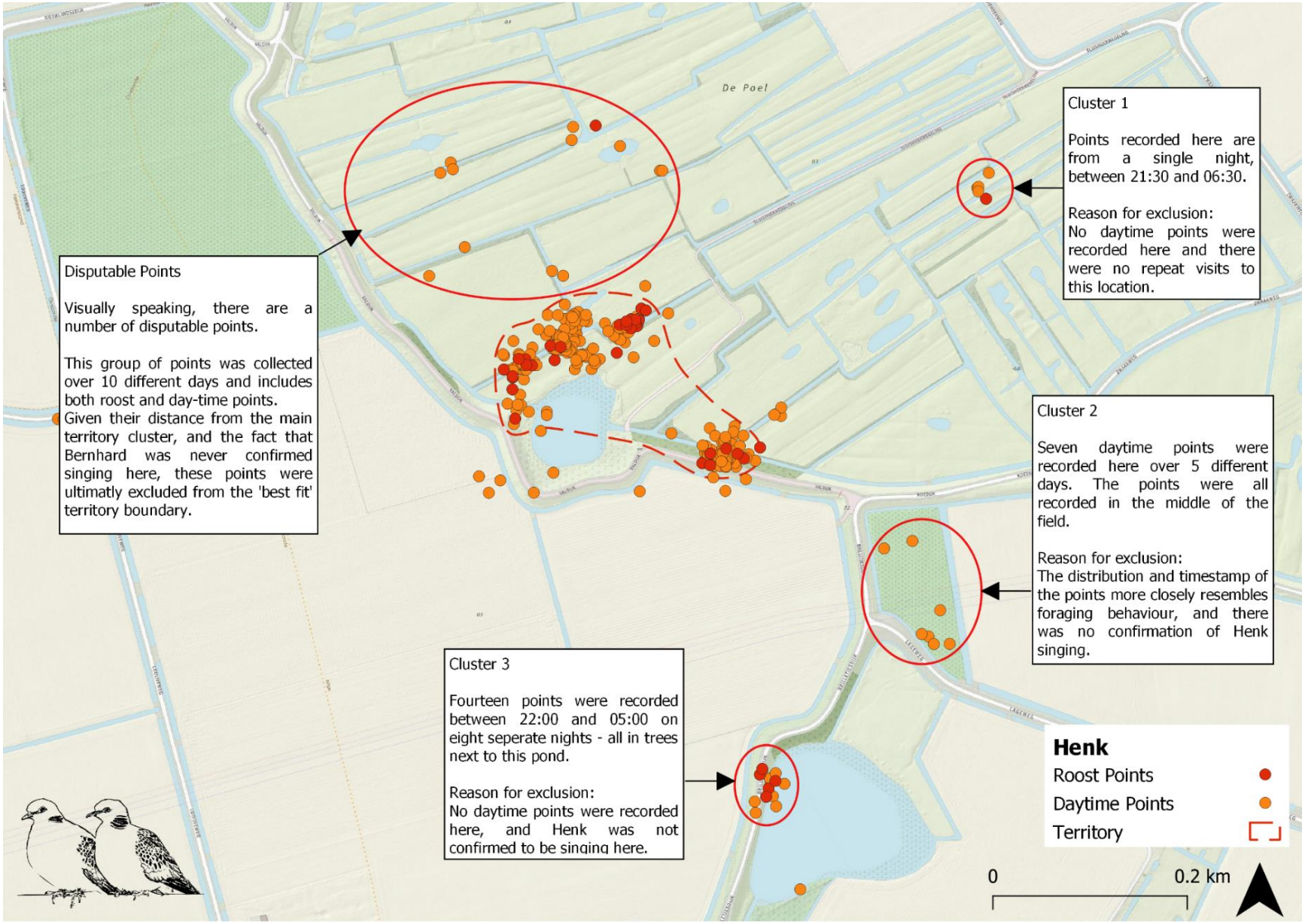


Appendix 13: Landscape features in Omi's territory

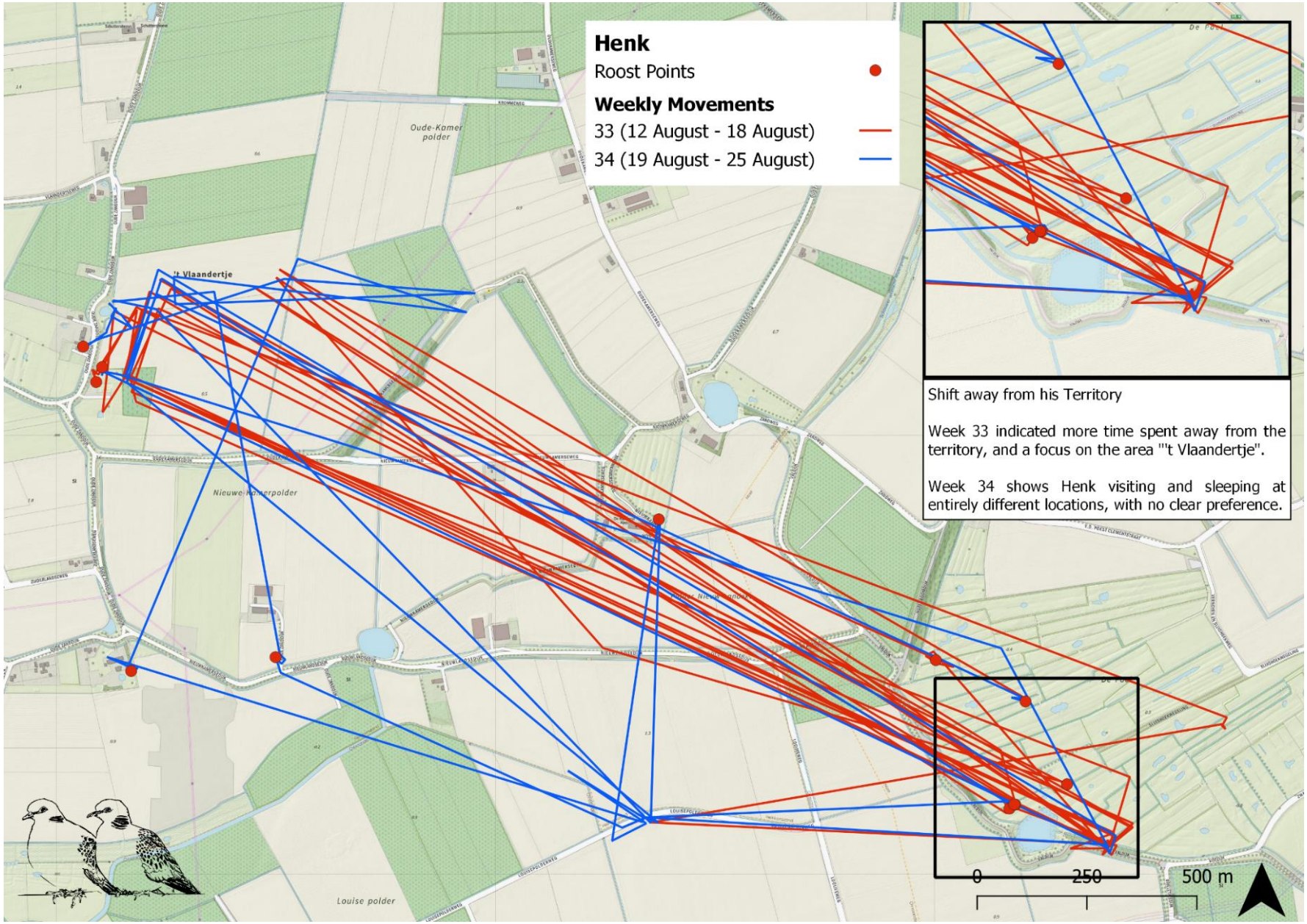


Appendix 14: Landscape features in Henk's territory

Appendix 15: Disputable points around Henk's territory

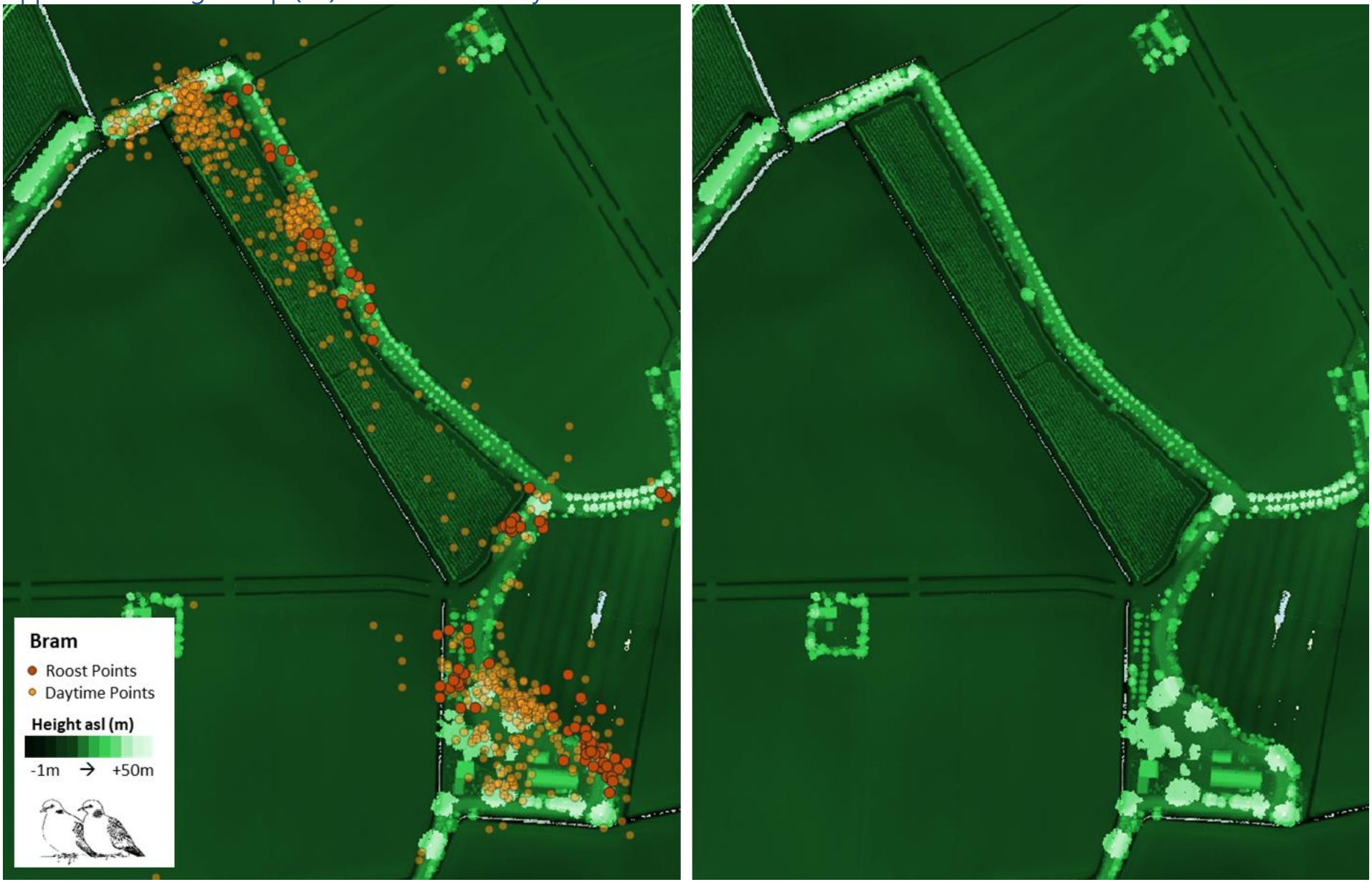


Appendix 16: Henk's final weeks of being monitored



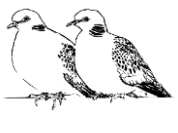
Appendix 17: Landscape features in Bram's territory

Appendix 18: Height map (asl) of Henk's territory



Appendix 19: Foraging sites and respective codes

Site	Address	Description/Key Land Uses
1	Nieuwkamerseweg	Crop
2	Nieuwkamersedijk	Crop - dike
3	Zandweg	Trees - pond
4	Nieuwkamersedijk	Blue poppyseed crop
5	Oudekamerseweg	Crop - buildings
6	Oude Zanddijk	Grassland mosaic of different habitats
7	Vlaandertseweg	Onion crop
8	Oudekamerseweg	Crop
9	Oudekamerseweg	Crop
10	Valdijk	Grassland-footpath
11	Valdijk	Footpath
12	Welhoek	Grassland (natural, grazed)
13	Noldijk	Orchard - stable buildings
14	Groenedijk	Mixed land use
15	Calagneweg	Grassland used for horse riding
16	Oude Noordweg	Dairy farmyard
17	Oud Ovezandseweg	Buildings
18	Brilletjesdij	Trees - pond
19	Ambachtsherendijk	Stable buildings
20	Nissestelle	Orchard
21	Nissestelleweg	Wheat crop
22	Nissestelleweg	Wheat crop
23	Ruigendijk-Korteweg	Gardens-grassland
24	Ruigendijk-Korteweg	Orchard - farmyard
25	Vissersdijk	Crop - grassland
26	Ellewoutsdijk	Crop - grassland
27	Dijkwelsestraat	Grass seed factory
28	Breijerweg	Dairy farm
29	Vierwegen	Orchard - grassland
30	Pietersweg	Orchard
31	Ruilverkavelingsweg	Orchard
32	Schuitweg	Gardens - grassland
33	Bergweg	Orchard - crop
34	Everdijkse Bredeweg	Dairy farm
35	'S-Gravenpolderse Oudedijk	Trees - located next to glasshouses
36	Dijkwegje	Large plane tree
37	Noldijk	Orchard
38	Brilletjesdij	Trees - pond
39	Lageweg	Blackcurrant crop
40	Louisepolderweg	Roads - wheat crop
41	Looijveweg	Road
42	Nieuwlandsedijk	Road
43	Notenboomdijk	Mixed land use
44	Oudekamerseweg	Crop - buildings
45	Zuiderlandseweg	Berry/nut bushes crop
46	Oude Zanddijk	Grassland mosaic of different habitats
47	Oude Zanddijk	Blue poppyseed crop
48	Heinkenszandseweg	Mixed land use



Appendix 20: Land use categories and sub-categories

Land Use Category	Sub-Category
Crops	Fruit nursery Crops Unknown Edge
Orchard	Orchard Tree nursery
Green Manure	Green Manure
Fallow land	Unworked/untilled
Trees/Forest	Mixed Deciduous Coniferous Poplars
Other	Nature area Unknown Railway Other Public allotments Sea Dike
Grassland	Grassland – agricultural Grassland - nature Grassland - unknown Grassland - Edge Cemetery Campsite Wind Turbine Park
Buildings/Gardens	Buildings/Gardens Gardens and other
Road/Track	Road/Track
Water	Lake, pond Channel