The status of the Grey Partridge in the Netherlands

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Inhoud

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Summary

BirdLife Netherlands considers to file a complaint with the European Commission against the Netherlands, for failing to maintain or achieve an adequate population level of the Grey Partridge, thereby failing to comply with Community Law. The present report aims to provide background information on the population and conservation status of the Grey Partridge in the Netherlands. This information will be used by BirdLife Netherlands to support their complaint.

The current population size of the Grey Partridge is estimated at *c.* 4000 breeding pairs, while the breeding population in 1980 is estimated at around 40,000 and in 1950 at around 150,000 pairs. The short-term trend (2007-2018) is a yearly decline by 11%. In the Netherlands the conservation status of the species is unfavourable and it is classified as "vulnerable" on the national Red List of breeding birds. The hunt on the Grey Partridge has been closed since 1998 and the species was removed from the list of huntable species in 2017. The main driving factor of the large-scale population declines since the 1950s is habitat loss and deterioration due to agricultural intensification.

Favourable Reference Values can be estimated at: 150,000 breeding pairs for the Favourable Reference Population, 35,078 km² for the Favourable Reference Range (all of the Netherlands, with the exception of a few islands) and 7,500-15,000 km² for the Favourable Reference Area of suitable habitat. None of these values are currently reached.

To achieve the level of the Favourable Reference Population of 150,000 pairs, an area of 2,250 km² of high-quality measures is required, corresponding to 12.4% of all farmland, 25% of arable land, or 15-30% of the Favourable Reference Area of habitat. Currently, 127 km² of high quality measures for Grey Partridges are implemented (i.e. less than 6% of the surface required to restore the FRA of habitat). Therefore, an additional 2,077 km² of high-quality measures are needed. In addition, the quality of these measures should be further increased to qualify as high quality measures for Grey Partridges, as currently in most AES-measures there are no restrictions on pesticide use, and no minimum width or minimum distance between nesting and chick rearing habitat is required.

Samenvatting

Vogelbescherming Nederland overweegt een klacht in te dienen bij de Europese Commissie tegen de Nederlandse staat wegens het niet in stand houden of bewerkstelligen van een adequaat populatieniveau van de Patrijs in Nederland en daarmee het niet naleven van het Europees recht. Dit rapport heeft tot doel om achtergrondinformatie te geven over de populatieomvang, trends en de staat van instandhouding van de Patrijs in Nederland. Deze informatie dient ter ondersteuning van de beoogde klacht die Vogelbescherming Nederland in voorbereiding heeft.

De huidige populatiegrootte van de Patrijs wordt geschat op circa 4000 broedparen, terwijl de broedpopulatie in 1980 wordt geschat op ongeveer 40.000 en in 1950 op ongeveer 150.000 paren. De korte termijn trend (2007-2018) is een jaarlijkse daling met 11%. In Nederland is de staat van instandhouding van de soort ongunstig en staat hij als “kwetsbaar” op de nationale Rode Lijst van broedvogels. De jacht op de Patrijs is sinds 1998 gesloten en de soort is in 2017 van de lijst van bejaagbare soorten geschrapt. De belangrijkste oorzaak van de grootschalige afname van de populatie sinds de jaren vijftig is habitatverlies en -verslechtering door intensivering van de landbouw.

In dit rapport worden zogenaamde “Gunstige Referentiewaarden” geschat volgens internationale systematiek. De Gunstige Referentie voor het aspect ‘Populatie’ (Eng.: Favourable Reference Population) wordt geschat op 150.000 broedparen, de Gunstige Referentie voor het aspect ‘Verspreiding’ (Eng.: Favourable Reference Range) wordt geschat op 35.078 km² (heel Nederland, met uitzondering van enkele eilanden) en de Gunstige Referentie voor het aspect ‘Leefgebied’ (Eng.: Favourable Reference Area of habitat) wordt geschat op 7.500-15.000 km². Geen van deze waarden wordt momenteel ook maar bij benadering bereikt.

Om het niveau van de gunstige referentiepopulatie van 150.000 broedparen te behalen is een gebied van 2.250 km² met kwalitatief hoogwaardige habitatmaatregelen vereist, overeenkomend met 12,4% van het huidige landbouwareaal, 25% van het akkerbouwareaal of 15-30% van de Gunstige Referentie-Leefgebied. Momenteel is - voornamelijk onder het stelsel van Agrarisch natuur- en Landschapsbeheer (ANLb) –127 km² aan hoogwaardige kwaliteit habitatmaatregelen voor de patrijs gerealiseerd (oftewel, minder dan 6% van het oppervlak dat nodig is om de Gunstige Referentiewaarde voor het aspect Leefgebied te herstellen). Daarom is er aanvullend 2.077 km² hoogwaardig habitat noodzakelijk voor een gunstige staat van instandhouding. Bovendien moet de kwaliteit van deze habitatmaatregelen verder worden verhoogd om te kwalificeren als effectieve maatregelen van hoge kwaliteit voor de Patrijs, omdat er momenteel in de meeste ANLb-maatregelen geen beperkingen zijn op het gebruik van pesticiden, en omdat er geen eisen worden gesteld aan de minimumbreedte van en/of minimumafstand tussen nest- en kuikenhabitat.

1. Introduction

As in the rest of Europe and in many farmland bird species, numbers of Grey Partridges (*Perdix perdix*) in the Netherlands have declined rapidly (https://pecbms.info/trends-and-indicators/species-trends/; Kleyheeg *et al.,* 2020). Conservation efforts so far have not been able to stabilise, let alone reverse, the decline. BirdLife Netherlands therefore plans to file a complaint with the European Commission against the Netherlands, for failing to maintain or achieve an adequate population level of the Grey Partridge, thereby failing to comply with Community Law. To substantiate this complaint, BirdLife Netherlands has asked Sovon to provide information on the status and trends of the species (chapters 2, 3 and 4), to determine the Favourable Reference Values (FRVs, chapter 5), and to compare the current amount of implemented conservation measures with the amount of measures required to achieve the FRVs (chapters 6 and 7).

2. Distribution and population size and their trends

The current distribution of the Grey Partridge, based on the Dutch breeding bird atlas updated with data from the Breeding Bird Monitoring Project (see below) until 2020 is given in figure 1. The Grey Partridge mainly occurs in the Southeast of the Netherlands, with some isolated populations in the bulb district in the west of the Netherlands. Highest densities are found in the southern part of the province of Zeeland. The current population size in the period 2017-2019 can be estimated at around 4000 (3500-4500) breeding pairs.

According to Van Kleunen *et al.* (2017), the distribution on the scale of 5x5 squared kilometres has halved, with most severe declines during the '80s and '90s. In the period after 2000, most of the remaining populations in the North and Central Netherlands have virtually disappeared and the populations in the South and East have become more fragmented (figures 1 and 2).

Grey Partridges are being monitored in the Breeding bird Monitoring Project (BMP), which started in 1983 and provides reliable trends for the Grey Partridge since 1990. By reconstructing Grey Partridge numbers in earlier years (mainly breeding bird atlases and grey literature, see box 1, table 1), we can additionally estimate the trend for the period 1960-1990, though this trend is less reliable than the trend after 1990 (figure 3). The species has declined by c. 96% since 1960, by 91% since 1980 and by 87% since 1990. The short-term (2007-2018) national yearly trend is 0.89 (trend classification 'strong decline'), which means the species is declining by 11% per year.
This reconstruction of historical population sizes also allows us to estimate the size of the breeding population in 1980, the year the Birds Directive came into effect; the breeding population in 1980 is estimated at around 40.000 (30.000-50.000) pairs. It should be noted that the breeding population was probably at least twice as large in the mid-seventies (figure 3), before the population crashed due to the severe winter of 1978-79. As Grey Partridges are sedentary the overall trend of the wintering population, estimated from point transect counts in winter (PTT), reflects the trend of the breeding population, be it with larger fluctuations (figure 3).

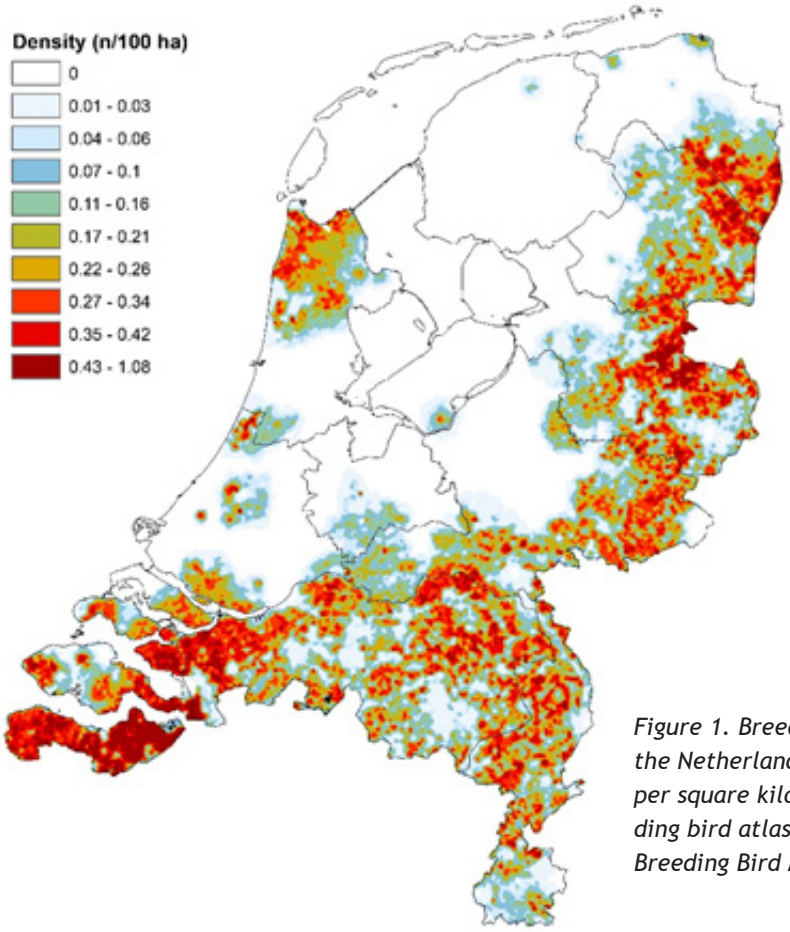

Figure 1. Breeding distribution of the Grey Partridge in the Netherlands in 2020. Density given in breeding pairs per square kilometre (100 ha). Based on the Dutch breeding bird atlas, updated until 2020 with data from the Breeding Bird Monitoring Project.

Box 1. Reconstructing population sizes

We started the reconstruction of historical population sizes by lining up the data sources available per year for the Grey Partridge since the 1950s. In table 1 a summary is provided of the basic data used for the yearly population estimates since the 1950s. The data sources vary between periods/estimates, e.g. based on work during the distribution atlas projects and yearly population indices based on monitoring efforts (see also table 1. from Foppen *et al.* (2017)). In case of indices we used the ratio of the average indices during 2013-15 and the total population estimate that was made for the atlas in that period to calculate a population size for each year.

Table 1. Data and methods used for estimation of historical population sizes of the Grey Partridge.

Period	Method	Description
1950	population estimate	based on regional data and a reconstruction of densities in the 1950s and more recent data we back-calculated the numbers*
1960-1989	indices old time series	in the 'Old Time Series' project (SOVON 2002) local time series are processed with TRIM to derive yearly national population indices (https://www.cbs.nl/nl-nl/maatschappij/natuur-en-milieu/indexen-en-trends--trim--)
1990-2020	indices monitoring scheme	the official monitoring scheme started in 1990 (NEM project: Sovon/CBS/Provinces). Local time series are processed with TRIM to derive yearly national population indices
2013-2015	Breeding Bird Atlas project	an estimate of the national breeding population

**The back-calculation from 2015 to 1960 leads to an estimate of around 180,000 in 1960. Assuming a decrease of 40% during the 1950s (Hustings et al. 2004) gives a figure of around 200,000 in 1950.*
An estimation of the change in densities between the 1950s and mid-1990s gives a factor 4-6 decrease (van Kleunen et al. 2005) which leads to an estimate of 120,000-180,000.
Based on these two approaches a conservative estimate was made of 150,000 breeding pairs at the beginning of the 1950s.

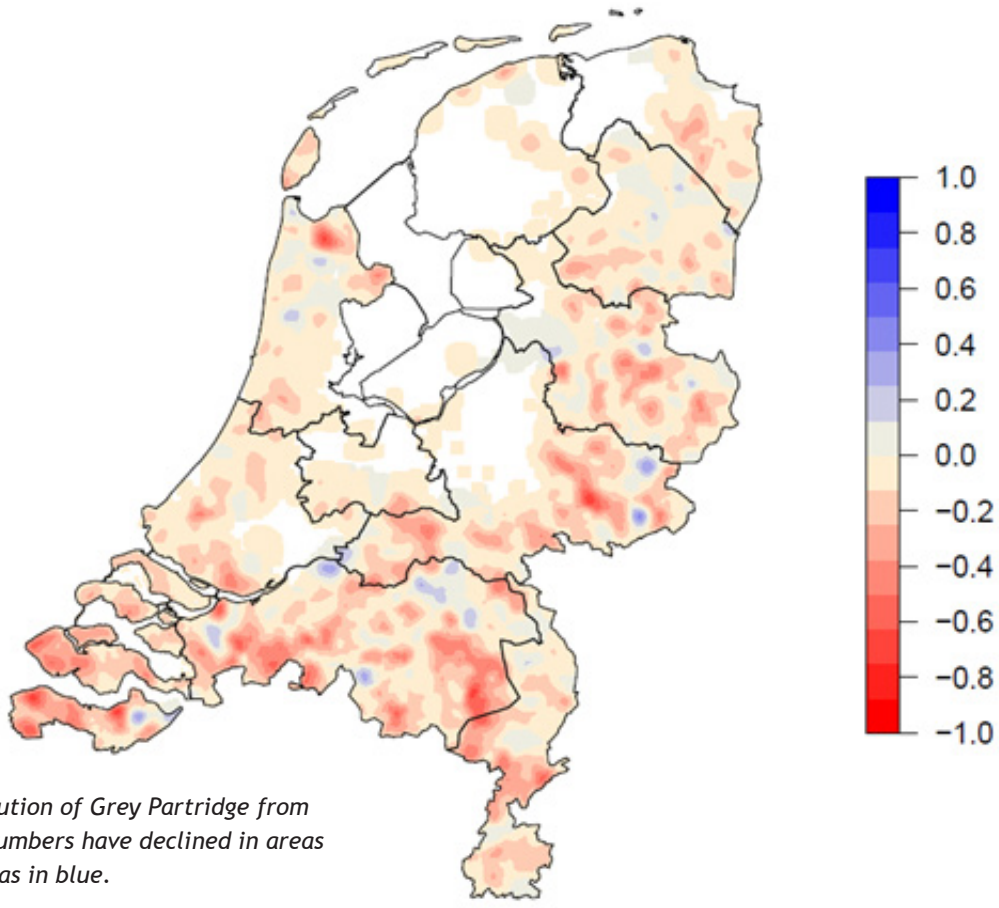

Figure 2. Change in distribution of Grey Partridge from 1998-2000 to 2013-2015. Numbers have declined in areas in red and increased in areas in blue.

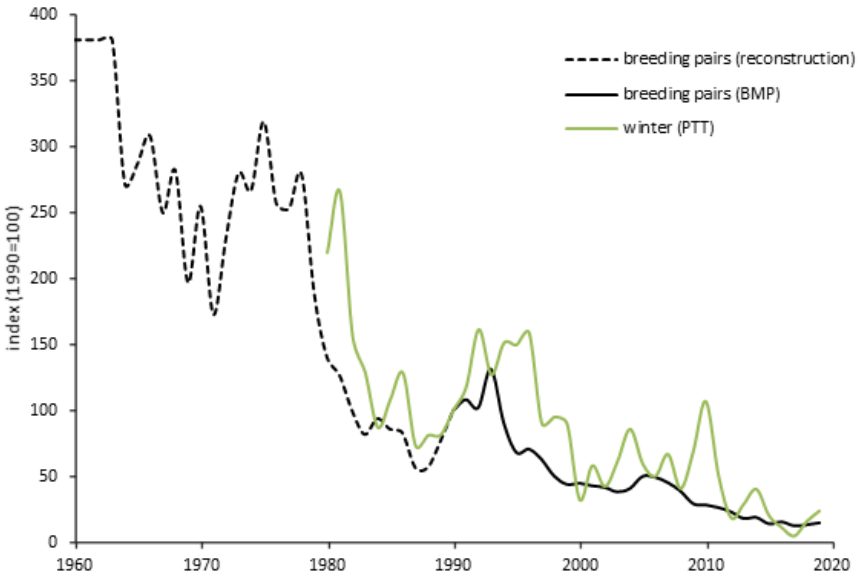

Figure 3. Trend of Grey Partridge in the period 1960-2019 (index value in 1990 fixed at 100). The trend of the breeding population in the period 1983-2019 is based on data from the Breeding bird Monitoring Project and is reliable since 1990. The trend before 1990 is less reliable and partly reconstructed from data from grey literature. The trend of the wintering population is based on data from point transect counts in winter and available from 1980 onwards. Sources: Network Ecological Monitoring, Foppen et al., 2017 and www.sovon.nl.

3. Threat status

The Grey Partridge is assessed as "Least Concern" on the Global Red List of Birds (BirdLife International 2021) and on the European and the EU Red List of Birds (BirdLife International 2015) due to its overall very large population and the resulting low risk of total extinction. It is however classified as SPEC 2 in the assessment of European birds of conservation concern (BirdLife International 2017) due to its unfavourable conservation status and the concentration of its world population in Europe.
In the Netherlands the current conservation status of the species is unfavourable (Vogel *et al.,* 2013) and it is classified as "vulnerable" on the national Red List of breeding birds (van Kleunen *et al.,* 2017). It has featured on the Red List since the first Red List of 1985 (Osieck 1986). On the first two Red Lists (1985, 1994) it was classified as "sensitive", but its ranking 'proceeded' to "vulnerable" on the following Red Lists (2004, 2016; Osieck 1986, Lina & van Ommering 1996, Hustings *et al.* 2004, van Kleunen *et al.* 2017).
In surrounding countries, the species is classified as 'threatened' (Germany, https://www.nabu.de/tiere-und-pflanzen/voegel/artenschutz/rote-listen/rote-liste-2021.html) or 'vulnerable' (Belgium: https://publicaties.vlaanderen.be/view-file/19270 and UK: https://britishbirds.co.uk/sites/default/files/BB_Dec21-BoCC5-IUCN2.pdf).

The hunt on the Grey Partridge has been closed since 1998 due to it featuring on the Red List (Staatscourant, 1 juli 1998, No. J. 985799) and the species has been removed from the list of huntable species since 2017 (Wet Natuurbescherming, artikel 3.20; wetten.overheid.nl/BWBR0037552/2017-03-01)

4. Causes of the decline

Kuijper *et al.* (2009) reviewed available literature on the decline of the Grey Partridge in Northwestern Europe and identified three periods with distinct trends and associated driving factors. Until 1960 in continental Europe (1950 in the UK), Grey Partridge breeding pair densities were high and populations were stable but fluctuating due to fluctuating (weather-dependent) chick survival. Between 1960-1980 (UK: 1950-1970) populations crashed as a result of a drop in chick survival rate caused by agricultural intensification. The associated increase in pesticide use (herbicides, insecticides and fungicides) reduced cover and chick food availability, as young chicks feed mainly on arthropods, while more efficient space use with increased field sizes and fewer field margins, hedgerows and wasteland patches, reduced availability of nesting and chick rearing habitat. After 1980 (1970 in UK), on top of the low chick survival due to agricultural intensification, increased predation rates, associated with low habitat quality, reduced nest and hen survival during incubation and likely also chick and winter survival. In some countries, hunting may also have contributed to declines in this period, especially when associated with game bird releases, as the latter renders hunting mortality independent of density. However, in the Netherlands, the Grey Partridge hunt has been closed since 1998 and game bird releases were banned in 1993, though illegal releases may still take place on a small scale.

After WW2, the use of chemical pesticides increased rapidly in the Netherlands. Unfortunately, little quantitative and historical data is present on pesticide use. Though the sales of herbicides and insecticides (expressed in the amount of active ingredients) has decreased slightly since the eighties (www.compendiumvoordeleefomgeving.nl), this gives no information on the toxic effects of these active ingredients or their formulations. Data on the area sprayed with pesticides is therefore likely to be more informative, although no information is included on the frequency of spraying. The use of pesticides in arable land is ubiquitous in the Netherlands; in 2016 92% of the area with arable and 89% of the area with cereals was sprayed at least once with herbicides, 38% and 62% respectively with insecticides and 61% and 89% respectively with fungicides (https://opendata.cbs.nl/statline/#/CBS/nl/dataset/84007NED/table?ts=1621334172012).

In the Netherlands, the first Land Consolidation Act, which aimed to improve the efficiency of farming, came into effect in 1924. However, due to economic factors and the Second World War, land consolidation took off only after 1950 and in the period 1950-1985 the area in execution increased rapidly. Due to a changing countryside with an increasing number of functions and actors the Land Consolidation Act was replaced by the Land Reconstruction Act in 1985 (van den Bergh, 2004). In the period 1950-1983, mean field size increased from 2.5 to 3.9 ha, in 1993 to 5 ha, but it declined again to 4.3 in 2008 (LEI & CBS, 2010). The length of vegetated field boundaries per 100 ha decreased with *c.* 54% from 1900 until 2003, with the most rapid decline in the period up to 1980 and after 1996 (Koomen *et al.,* 2007). In the period 1960-1994 30-50% of hedgerows were removed, often stimulated by the government (European Court of Auditors, 2020).
The obligatory set-aside regulation, introduced in 1988 to help reduce the surpluses produced in Europe and adapted several times since, led to an increase in area of set-aside from 6000 ha in 1990, to 24000 ha in 2000. However, after the set-aside regulation was withdrawn from the CAP in 2009, it decreased again to 8000 ha in 2013 and 9000 in 2020 (https://opendata.cbs.nl/statline).

In the Netherlands, numbers of most mammalian predator species have increased since 1950 (Fox, Badger, Beech Marten, Weasel), except for the Stoat, which declined in numbers (verspreidingsatlas.nl). Also some avian predator species have increased in numbers since 1984 (Goshawk, Buzzard), while others first increased and then decreased again (Carrion Crow: increase until *c.* 2005 then decrease, Sparrowhawk: increase until *c.* 1999, then decrease, sovon.nl).
Overall, predation pressure on eggs, chicks and adults is likely to have increased, due to an overall increase in predator numbers, exacerbated by an increased vulnerability to predation in a homogeneous landscape devoid of appropriate cover. However, too little data are available to quantify changes in predation pressure over the past decades.

Other, additive detrimental causes for the decline, mentioned in the Recovery plan for the habitat of the Grey Partridge (Ministry of Agriculture, Nature Conservation and Fisheries, 1991) are also associated with the intensification of agriculture: the increased prevalence of monocultures, especially maize, the increased use of fertilisers, leading to denser vegetation and the intensified use of grasslands, leading to earlier and more frequent mowing and higher cattle densities. In areas with low crop diversity, no or few alternative crops are present when food and

Figure 4. The distribution of grassland (green) and arable land (brown) in the Netherlands (BasisRegistratie Percelen).

cover disappear after harvest. Dense vegetation is unsuitable for breeding and early and frequent mowing destroys nests and removes cover. Intensively managed grasslands have therefore lost their value for breeding Grey Partridges and the species has nearly disappeared from previously occupied (figure 7) large-scale grassland areas in the north and west of the Netherlands (figures 1 and 4), and nowadays only one quarter of the population can be found on grassland (Bos *et al.,* 2010).

In conclusion, the main driving factor of the large-scale population declines since the 1950s is habitat loss and deterioration due to agricultural intensification.

5. Favourable Reference Values

To determine the Favourable Reference Values (FRVs) of the Grey Partridge, we used the provisional method described in Vogel *et al.* (2021), a proposition to the Ministry of Agriculture, Nature and Food Quality for determining the conservation status of Dutch birds. First we describe some definitions and principles.
The Birds Directive (BD) does not include the concept of a 'favourable conservation status', as defined and used in the Habitats Directive (HD), and thus does not specify a clear procedure for determining the conservation status of birds. Most concepts and definitions originate from the HD and if a specific definition is not provided by the BD, the definition from the HD is leading.
The HD (but not BD) defines the so-called Favourable Reference Values (FRVs): *"minimum ecological requirements to maintain the population on a long-term basis as a viable component of its natural habitats (DG Environment, 2017) or ecosystems*" (AEWA/EGMIWG/4.16/Rev.1). These are therefore minimum values based on ecological grounds only, which safeguard that the species will not go extinct and that it can soundly fulfill its ecological role in the habitats/ecosystems in which it naturally occurs. The equivalent aim formulated in the BD is: "*to maintain or restore EU bird populations at a level which corresponds in particular to their ecological, scientific and cultural requirements, while also taking into account economic and recreational needs.*" (BIRDS DIRECTIVE 2009/147/EC, article 2). As an elaboration of this aim, the Dutch Ministry of Agriculture, Nature and Food Quality defined national population goals (Ministerie van LNV 2006). These goals formulated for species with an unfavourable conservation status could be viewed as the first Dutch elaboration of the Favourable Reference Populations (FRPs) to meet the population level required by the BD, but the formulation of these goals does not follow the procedure developed and applied for the HD.
According to the guidance documents of the Habitats Directive (DG Environment 2017) FRVs should be formulated for three different aspects: the Population (FRP), the Range (FRR) and the Area for habitat (FRA). We used the guidance document and examples of Bijlsma *et al.* (2019) to apply these principles to bird species.

Favourable Reference Population (FRP)

The FRP can be determined by answering the question: How many breeding pairs of the Grey Partridge are required in the Netherlands, for it to establish and maintain an ecologically sustainable element

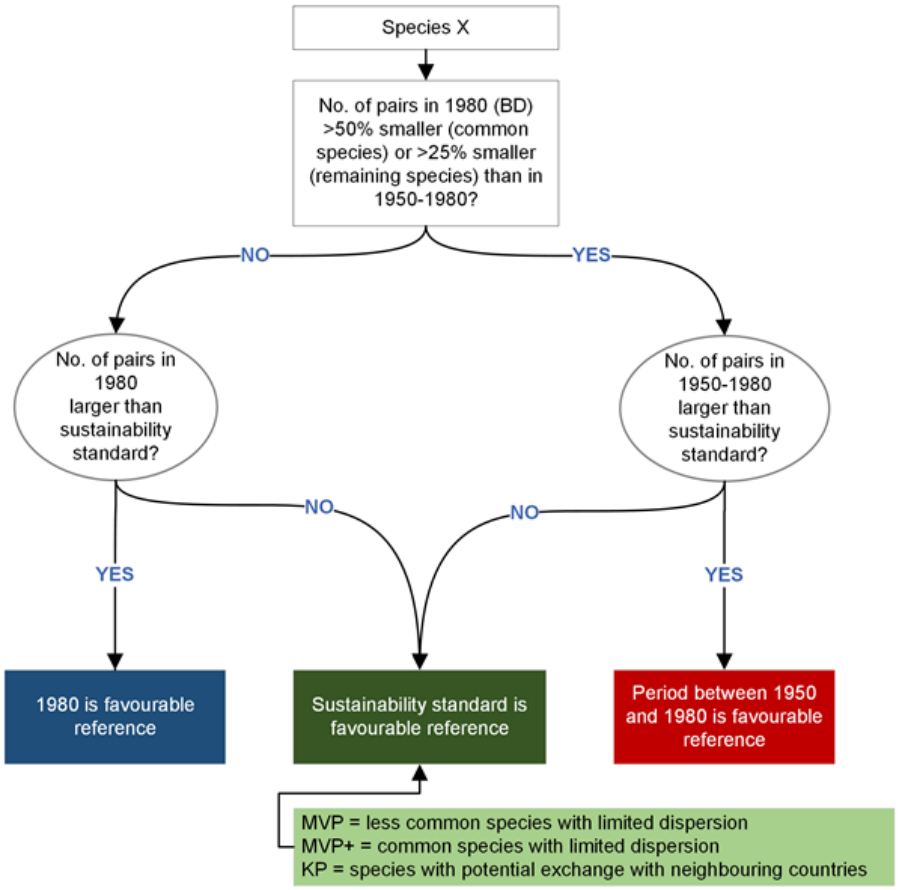

Figure 5. Decision tree for determining the Favourable Reference Population size in birds (Vogel et al., 2021).

Table 2. Minimum required population sizes estimated using different methods and the resulting FRP value.

Population size based on	Number of breeding pairs	Method
MVP value	770	Based on weight and allometric relation proposed by Hilbers *et al.* (2016)
MVP+ value	7700-11050	Based on MVP and multiplication factors given in Green *et al.* (2020) and Bijlsma *et al.* (2019)
1950	150000	Reconstructed population size used in the Red List (van Kleunen, 2017), see table 1
1980	41600	Based on reconstructed population size from grey literature (Foppen *et al.* 2017)
conclusion:		
FRP	150000	150,000 is the estimated population size in the 1950s (see box 1)

of the habitats/ecosystems in which it occurs (after Bijlsma *et al.*, 2019)?
Vogel *et al.* (2021) defined and applied the following principles for estimating the FRP:

- The FRP should at least equal the population level in the year in which the Birds Directive came into effect (1980)
- The FRP should be large enough to ensure a viable population level. Hence, it is necessary to determine the minimum value for a viable population. This value can be used to determine whether the population size is large enough for the species to remain a viable component of its habitat. The following 'sustainability standards' can be applied:
  - MVP (Minimal Viable Population): a minimum value for the number of individuals in an isolated but continuous population to be able to withstand the effects of demographic and environmental fluctuations.
  - MVP+: Sometimes a buffer is added to the MVP, to prevent declining populations from overstepping this critical value (Green *et al.* 2020, Bijlsma *et al.* 2019).
  - Key population (KP): critical values can be determined for key sites or key populations within a metapopulation, for species with potential exchange with neighbouring countries. These will depend on the dispersal ability of the species.
- The reference year 1950 is considered important, because it is used as the reference year, or period (the 1950s) for composing the Red List for breeding birds. It should particularly be considered for species which have shown a significant decline in the period up to 1980, as the population in this period should be considered to be "healthy".

These aspects are combined in a decision tree (figure 5, Vogel *et al.* 2021).

The resulting minimum population sizes, as well as the concluded FRP, are given in table 2 and visualised in figure 6. For the Grey Partridge, the estimated population size of the 1950s (see box 1 for method of estimation) is used as the Favourable Reference Population because since the 1950s the species has declined rapidly, a decline which has not stopped since then, i.e. no stable periods could be detected which could act as an alternative ecologically favourable situation.

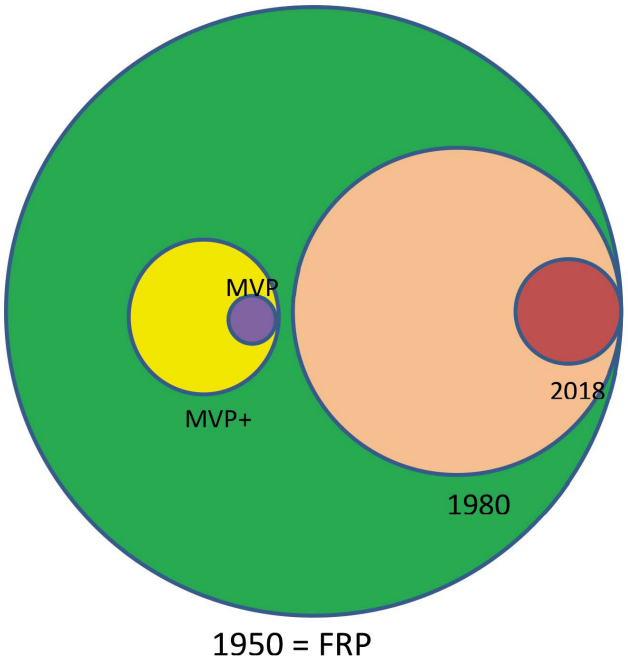

Figure 6. Partridge population size estimates for the Netherlands in different periods (1950, 1980, 2018) and minimum required partridge population sizes (MVP, MVP+) estimated using different methods and the resulting Favourable Reference Population size value.

Favourable Reference Range (FRR)

The FRR can be determined by answering the question: What minimum range is needed in the Netherlands to safeguard the long term survival of the species in its natural habitat (after Bijlsma *et al.*, 2019)?
Clearly, the FRP should 'fit' into this range, meaning that the expected maximum population size within an FRR cannot be smaller than the FRP. The FRR acts as a geographical envelope for the FRP and FRA.

Table 3. The Favourable Reference Range calculated using the distribution map of 1973-77 (Teixeira, 1979) and the Range Mapping Tool.

Aspect	Range area (km²)	Method
FRR	35078	Conversion of 10 x 10 km species distribution map of 1973-77 using the Range Mapping Tool

To facilitate the estimation of the FRR for the HD and BD reports, the European Environmental Agency has devised a Range Mapping Tool. This tool converts a 10 x 10 km species distribution map (ETRS 89 grid cells in the ETRS LAEA 5210 projection) into a species range, by filling up gaps in the distribution using species specific parameters, which depend on the dispersal ability of the species. For this conversion the distribution of the species in the Favourable Reference year or period should be used, which can be derived from the FRP, in the case of the Grey Partridge 1950. However, no data are available on the distribution of the species in 1950. As the major decline in population range occurred during the 1980s and 1990s (van Kleunen *et al.,* 2017 and figure 3, accounting for the temporary population recovery in the mid-seventies) and the range probably remained more or less stable before this period (Osieck 1986), we used the species distribution map from the period 1973-1977 (breeding bird atlas, Teixeira, 1979). The FRR covers nearly all of the Netherlands, with the exception of a few islands (such as Vlieland and Rottumeroog, figure 7). The total size is 35,078 km².

Favourable Reference Area for habitat (FRA)

For the Favourable Reference Area for habitat both size and quality are important. The lower the habitat quality, the larger the area needed to harbour the FRP. Projecting the population size in 1950 (150,000 breeding pairs) on the breeding range in 1950 (35,078 km²), gives an average density of 4.3 breeding pairs per km² (bp/ km²). However, part of the breeding range consists of land use unsuitable

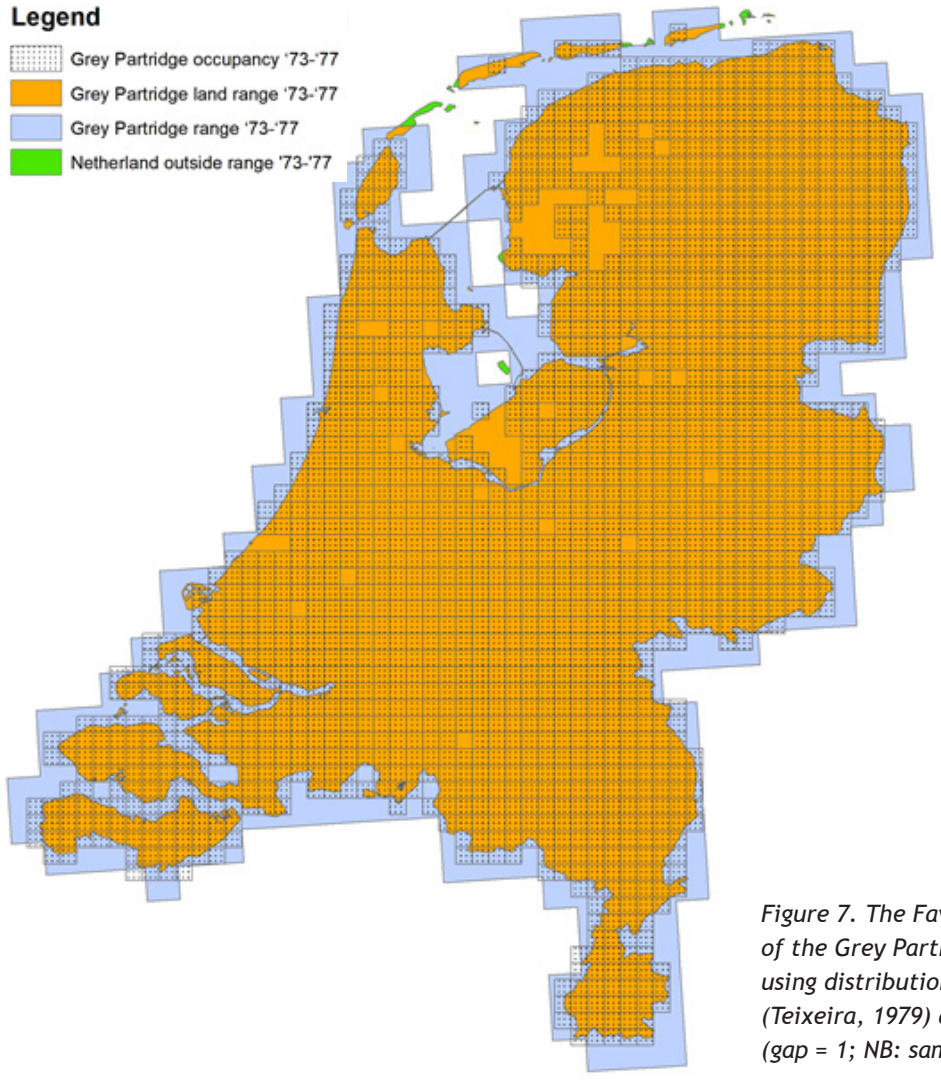

Figure 7. The Favourable Reference Range of the Grey Partridge (in orange), estimated using distribution data from the period 1973-77 (Teixeira, 1979) and the Range Mapping Tool (gap = 1; NB: same results with gap = 2).

for Grey Partridges. In 1950, the surface area under agricultural use was 23,350 km² (statline, cbs.nl). Assuming nearly all Grey Partridges bred in agricultural areas, the mean breeding density was around 6.4 bp/ km². Breeding densities are higher on arable than on grassland (Doude van Troostwijk 1968, Bos *et al.,* 2010). Assuming a distribution of the population of 26% on grassland (13,200 km² in 1950, statline) and 74% on arable (10,200 km² in 1950) (Bos *et al.,* 2010: 53% of population on arable, 28% on mixed and 19% on grassland), average breeding densities on arable land were probably around 11 bp/ km² in 1950.

In the Netherlands, Doude van Troostwijk (1968) found maximum densities in September of 57 individuals/ km² in arable land in the sixties. Assuming a young:adult ratio of around 3 (Doude van Troostwijk, 1968) and spring survival of *c.* 50%, these would translate to *c.* 14 bp/ km² in spring, which fits nicely with our estimated average density in Dutch arable land of 11 bp/ km² at that time. In Nederweert, a municipality in the province of Limburg, maximum densities of 9 bp/ km² could be found in 1994, which declined to 3 bp/ km² in 2018 (Loven *et al.,* 2018). Bult (2007) estimated maximum densities of 10-15 bp/ km² in a few small areas in West-Brabant in 1989-1996. In Poland, maximum densities amounted to 18.7 bp/ km² (Panek, 2006). According to Flade (1994) breeding densities in half open landscapes in Germany in the eighties were around 5-13 bp/ km². These densities were probably higher before 1980.

Higher maximum density estimates are given for northern France and England, but these densities are probably less representative of the Dutch situation, where releases are illegal and predator control is controversial. In northern France, breeding pair densities vary between 5-50 bp/ km² (Issa & Muller, 2015, Keller *et al.,* 2020). However these high densities may be caused by game bird releases (Keller *et al.,* 2020). In England, Potts & Aebischer (1994) give maximum breeding densities of 21 bp/ km² in 1968 in a study site in Sussex, while Ewald *et al.* (2020) give similar maximum densities in 2010-2016 in the part of this site specifically managed for Grey Partridges. Aebischer & Ewald (2010) arrive at 18 bp/ km² in favourably managed habitat in Hertfordshire. Even higher maximum densities of 54 bp/ km² were reached at a demonstration site in Norfolk (Draycott, 2012). However, at all three English sites intensive lethal predator control and supplementary feeding were part of the restoration programme, besides the creation of favourable habitat.

With maximum densities of 10-20 bp/ km², one would need 7,500-15,000 km2 of favourable habitat, to reach the FRP. As arable land currently (2020) covers *c.* 9,100 km² (including fodder and non-greenhouse-horticulture; opendata.cbs.nl/#/CBS/nl/dataset/71904ned/table?ts=1626188786740), this means that in the most optimistic scenario nearly all (82%) and in the least optimistic scenario all land under arable use and 66% of the grassland area (currently *c.* 9,000 km², opendata.cbs.nl/#/CBS/nl/dataset/71904ned/table?ts=1626188786740) should consist of favourable habitat for the Grey Partridge. Considering the fact that Grey Partridges have already disappeared from part of the Dutch farmland and that the species has a low dispersal ability, it will take a long time for the species to recover to the level of the FRP, even when all farmland habitat is optimised for the Grey Partridge.

Table 4. The size of the Favourable Reference Area for habitat based on the FRP value of 150,000 and maximum densities of 10-20 bp/ km².

Aspect	Km²	Method
FRA	7500-15000	*Calculated using the FRP value of 150,000 and maximum densities of 10-20 bp/km²*

6. Measures for partridge protection

Several measures to improve habitat conditions for Grey Partridges have already proven to be effective. As described above, the main bottlenecks for partridges occur during the breeding season. Partridges prefer to nest in permanent vegetation providing good cover in spring. Potts (1980) has shown that the carrying capacity for Grey Partridges is determined by the amount of nesting habitat in the form of hedges and grassy perennial vegetation in field edges. Increasing the length of these features will therefore increase both nest success and the density of breeding pairs.
Chicks are preferably reared in insect-rich and accessible annual vegetation and restoring chick rearing habitat is pivotal for conservation of the species (Aebischer & Ewald, 2004). Effective management should therefore focus on increasing both nesting cover and chick rearing habitat (Aebischer & Ewald, 2004). In projects in England this is achieved by providing hedgerows and beetle banks for nesting and unsprayed strips of cereals (conservation headlands), wild bird cover and cultivated arable margins as chick-rearing habitat. The British "stewardship" scheme, an agri-environment measure under the EU's Common Agricultural Policy, guarantees the proximity of these measures to one another, by implementing a high density of measures at the level of a farm. In Lower Saxony in Germany both habitat types are provided in the form of biannual flower blocks, which are cultivated annually on 50% of each block; after one year the treatment is reversed and the other half is re-sown (Gottschalk & Beeke, 2014). This type of flower block or strip has been implemented as an agri-environment scheme in some German federal states and more recently also in the Netherlands, e.g. in the Interreg-project PARTRIDGE (see below) due to its proven effectiveness.
Measures should be implemented in blocks or broad features (> 10 m, but preferably > 20 m) rather than narrow strips (< 10 m), as predation rates are high in narrow strips (Bro *et al.,* 2004). Gottschalk & Beeke (2014) found that the predation risk of nests (and sometimes incubating hens) was twice as high in strips with a width <10 m than in blocks or strips with a width > 10 m.

Though several AES-options exist in the Netherlands to provide nesting or chick rearing habitat, there is no requirement for the two types of measures to be combined (except for the new measure 'biannual flower blocks'), only in a few cases an appropriate minimum-width or resting period is required (period without agricultural activities, should be from April to August) and though the use of herbicides is usually restricted, the use of insecticides is permitted in all but 2 of the AES-measures.
In addition, some other AES-measures exist, such as stubble fields and winter food crops, which aim to provide winter cover and food to improve overwinter survival, which can help to maintain Grey Partridge densities overwinter – once chicks are produced. An overview of AES-measures and their relevance for Grey Partridge conservation is given in Appendix 1.

In England, habitat measures for Grey Partridges are usually accompanied by lethal predator control, which can be very effective when implemented at high intensity and aimed at several predator species during the breeding season (Tapper *et al.,* 1996). Predator control is not effective at low intensity (Baker & Harris 2005, Lieury *et al.* 2015), and therefore only feasible on a small-scale.
Lethal predator control is controversial in the Netherlands and often only applied (if at all) in grassland areas rich in meadow breeding waders, but poor in partridges. Moreover, predator control is only allowed if all other options (i.e. habitat management) have been implemented and have proven insufficiently effective, and if predator populations are in a favourable conservation status. Measures should therefore focus on improving the habitat sufficiently for the partridge population to withstand current predation pressure and on providing habitats that minimise predator effects – i.e. ensuring that habitat measures have widths > 10 m and preferably even > 20 m.

7. Quantitative comparison of measures required vs. implemented

In 1991, the Ministry of Agriculture, Nature Conservation and Fisheries drafted a 'Recovery plan for the habitat of the Grey Partridge'. The aim of this recovery plan was to improve partridge breeding habitat, by setting up demonstration projects across the country which would then stimulate other landowners to adapt their management for the benefit of Grey Partridges. In these demonstration sites, the aim was to double partridge densities to at least 5 bp/ km² within 5 years. An evaluation of the project showed that at these sites, on average 4 km of field margins were created per km² (e.g. uncultivated grassy margins, extensively managed road sides and hedges). Partridge densities remained stable at 4 bp/ km² at the demonstration sites, while they decreased to 2 bp/ km² at control sites. However, the breeding success at the demonstration sites decreased during the project, while it remained stable at the control sites, and the measures failed to increase breeding densities (Maris 1997). The author mentions two possible causes for this: 1) a lack of chick rearing habitat, as only few farmers were willing to cease the use of pesticides in margins of cereal fields or 2) density dependent predation. In hindsight, another explanation could be that the created field margins were too narrow, ranging between 3-9 m, which increased predation rates (see above). The large amount of field margins may therefore have attracted breeding pairs from the surroundings, which seemingly stabilised the breeding densities, but may have simultaneously increased mortality rates of eggs, chicks and possibly breeding hens. The project was expanded to 23 follow-up sites, together harbouring an estimated 750 breeding pairs of the Grey Partridge, only *c.* 6-8% of the population at that time (9.000-13.000 in 1998-2001, Hustings, 2001). The actions from the recovery plan failed to halt the decline of the Grey Partridge (figure 3).

More recently, the Grey Partridge has been included as a target species for Agri-Environment Schemes in 10 out of 12 provinces and 17 AES-measures aim at improving conditions for Grey Partridges (Boerennatuur, 2021, Appendix 1). The total surface area under these AES-measures amounted to 395 km² in 2020. When only considering the high quality measures which are likely to be effective (e.g. providing nesting or chick-rearing habitat, Appendix 1) the total surface area was 127 km². However, Grey Partridges nowadays occur in only part of the (farmland) area. When only the AES-measures within the partridge distribution are considered (based on figure 1), the total surface area amounts to 167 km² for all partridge measures and 69 km² for the high-quality partridge measures.

In addition, some nature conservation measures in farmland reserves, aiming at increasing biodiversity on arable land, in the form of herbs, birds and/or Common Hamsters are relevant for Grey Partridges (Appendix 1). The total area under these measures was 46 km² in 2020; the area with nature conservation measures within the Grey Partridge distribution was 35 km².
Finally, in many regions additional measures are taken for Grey Partridges, but usually on a small scale, with a negligible effect on the area of measures on a national scale. An overview of the collated data can be found in Appendix 2.
The total estimated area of the distribution of Grey Partridges is 22,402 km². Comparing the area of habitat provision to the distribution of Grey Partridges indicates that 0.9% of the area within the partridge distribution is covered by all types of measures that may benefit partridge conservation, with slightly over half (0.5%) of only high-quality measures.

Gottschalk & Beeke (2014) observed a nearly tenfold increase of the breeding population of Grey Partridges to *c.* 20 pairs in an area of around 650 ha in which 3-7% of the arable land was converted to biannual flower blocks (20-45 ha of flower blocks). When flower blocks constituted only 0.8% of the area, as in the whole of the district of Göttingen, this led to a stabilisation of the present numbers. Based on these data they state that each Grey Partridge pair needs *c.* 1.5 ha of high-quality measures such as the biannual flower blocks and that *c.* 3-7% of the habitat should consist of such measures for populations to increase. Aebischer & Ewald (2004) show that on arable land in England, *c.* 4% of arable area is needed as insect-rich brood-rearing habitat to maintain stability, while 6% of such habitat would increase chick survival to a pre-pesticide level. Though these percentages were obtained from a different country with a different landscape and predation management tradition, and possibly partly different underlying causes for the decline (UK: main proximate cause: decreased chick survival; Germany: main proximate cause: predation of nests and breeding hens), they are very similar to the 3-7% estimated by Gottschalk & Beeke (2014).

Assuming every breeding pair needs 1.5 ha of high-

Table 5. The surface area of high-quality measures required for stabilisation of the current situation, for population growth and for the FRP.

Target	Area of high-quality habitat required (km²)
FRP: 150,000 bp	2250
stabilisation of current population	123-369 (on arable)
population growth	614-860 (on arable)

quality habitat, as stated by Gottschalk & Beeke (2014), to achieve the level of the Favourable Reference Population of 150.000 pairs, one would need an area of 225.000 ha (= 2250 km²) of high-quality measures, corresponding to 12.4% of all farmland, 25% of arable land, or 15-30% of the Favourable Reference Area for habitat (see figure 8). This would mean that an additional (2250 – 127 - 46 =) 2077 km² of high-quality measures are needed, a 13-fold increase in the area of high-quality measures in 2020. In addition, the quality of these measures should be further increased, as in most AES-measures there are currently no restrictions on pesticide use, and no minimum width or minimum distance between nesting and chick rearing habitat is required.

To stabilise the population on arable land at the current level, one would need *c.* 1-3 % of arable land under high-quality measures, which would amount to 91-273 km². As *c.* 26% of the population breeds on grassland and will not benefit from these measures, the area with high-quality measures on arable should be larger, namely 123-369 km².
For the population to increase, *c.* 5-7% of arable land should consist of high-quality measures, and this needs to increase to 7-10% where 74% of the population breeds on arable – as is the case in the Netherlands. This corresponds to 614-860 km² of high-quality measures on arable farmland.
The area of high-quality measures (mainly on arable but also on grassland) within the Grey Partridge breeding distribution is currently 104 km², clearly insufficient to stabilise the population.

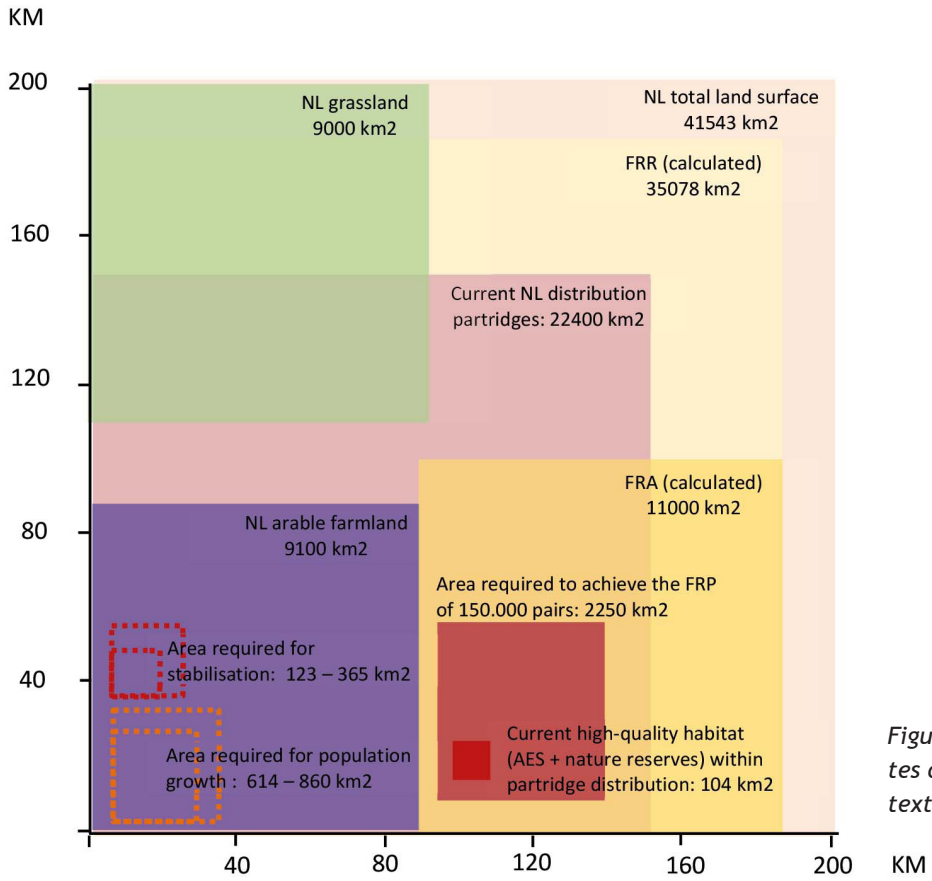

Figure 8. Different surface estimates discussed above, for details see text.

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Appendix 1. Overview of relevant Dutch AES-measures

Overview of Dutch AES-measures considered to be relevant for Grey Partridge conservation (Boerennatuur, 2021).
Life-cycle stage: n = nesting, c = chick rearing, w = winter
Relevance Collectives: weight given to measures according to the judgement of Collectives (Boerennatuur 2021). Measures with a limited contribution to partridge conservation received weight 0.5, those with a large contribution received weight 1.
Quality: weight given to measures according to quality, based on expert judgement and literature (see chapter 6), and used in calculations of measures implemented. High quality measures receive weight 1, measures of moderate quality receive weight 0.5, measures considered irrelevant for Grey Partridges receive weight 0.

measure	measure in Dutch	code of measure	life cycle stage	relevance Collectives	quality	clarification
grassland with delayed mowing	grasland met rustperiode	1a-h,l,m,q-t	(n)	0.5	0	designed for meadow breeding waders, only suitable if mowing delayed > 1 august, vegetation often too dense
		1i-k,n-p	n	0.5	0.5	mowing delayed > 1 august, but vegetation often too dense
chick grassland	kuikenvelden	2a-e	(c)	1	0	location flexible and based on broods of meadow breeding waders, required periods without mowing too short, vegetation too dense and monotonous, not selected by GP
herb-rich grassland	kruidenrijk grasland	5a-f	n	1	0.5	suitable vegetation,but too early mowing allowed
		5g,j,k	n	1	1	suitable vegetation, and restrictions on mowing
extensively grazed pasture	extensief beweid grasland	6a,c	n	1	0.5	cattle density too hig for nesting, low suitability for chicks
		6b	c	1	1	only very low cattle densities allowed
rough manure	ruige mest	7a	(c)	0.5	0	in itself not sufficient, only relevant in combination with other measure
botanical grassland	botanisch grasland	13a-e	c	0.5	0.5	suitable for nestw and chicks, but no restrictions on mowing and cattle densities
		13f,g	c	0.5	1	suitable for nestw and chicks, no activities during chick phase
stubble fields	stoppelland	14a-d	w	1	0.5	not aimed at reproduction, management restrictions only in winter
winter food crops	wintervoedselakker	15a,b,d	w	1	0.5	not aimed at reproduction, management restrictions only in winter
		15c	n,c,w	1	1	also suitable for reproduction
bird field	vogelakker	16a-c	n,c,w	1	1	but suitability depends on composition of field margins, determined by Collective
hamster field	bouwland voor hamsters	17a,b	c,w	1	1	designed for Common Hamsters, suitable for chickrearing and winter
herb-rich field	kruidenrijke akker	18a-f	c	1	1	herbicides not allowed (but no restrictions on other pesticides)
herb-rich field margin	kruidenrijke akkerrand	19a-c,g	(n,c,w)	1	0	width < 10 m
herb-rich field margin	kruidenrijke akkerrand	19d-f,h-l	n,c,w	1	1	width > 10 m
coppice management	hakhoutbeheer	20a-e	n	0.5	0.5	no restrictions on height, only on management
hedgerow	struweelhaag	23a	n	0.5	1	suitable for breeding
		23b	n	0.5	0.5	suitable for breeding, if not too high
hedgerow margin	struweelrand	24a	n	0.5	1	suitable for breeding
insect-rich grassland	insectenrijk grasland	31a	c	0.5	0.5	suitable, but mowing during breeding season
		31b	n,c	0.5	1	suitable for breeding
insect-rich grassland margin	insectenrijke graslandrand	32a	n,c	0.5	1	suitable for nest and chick rearing, but no minimum width required
bird cereals	vogelgraan	40a	c,w	0.5	1	suitable for chicks and winter
		40b	c	0.5	0.5	suitable for chicks, but during limited period
herb- and invertebrate-rich field	kruiden- en faunarijke akker	N12.05	n,c,w	1	1	nature conservation management for biodiversity on fields

Appendix 2. Additional measures implemented regionally

In many regions, both AES- and other additional measures are implemented for Grey Partridges, by local people and organisations. To get an impression on the total surface area involved, the quality of those measures and the associated breeding pair densities, we asked the Dutch network of partridge enthusiasts established within the Interreg PARTRIDGE-project, for data collected within their local projects.
An overview of the collated data is given in table A2.1.
Figure A2.1(a) does not show a clear relationship between the percentage of measures implemented and the resulting Grey Partridge densities. However, no selection was made of the type and quality of measures, as this often proved impossible (table A2.1); i.e. some measures included may not be suitable for Grey Partridges.

Table A2.1. Metadata on partridge measures implemented within regional projects.

organisation	province	area of measures provided?	area of measures in 2020 (km²)	AES?	other measures	count data available?	selection relevant measures possible?
ANV Hollands Noorden	NH	yes	5.5	yes	no	yes, count data and reproductive output, only 2020	yes
ANLV Geestgrond	ZH	no		no	yes	yes, BMP-W Sovon: numbers declined since 2002 from 15 to 2 bp/km2, stable since 2010	no
PARTRIDGE, Het Zeeuwse Landschap	Zl	yes, but no GIS	1.0	no?	yes	yes, standardised counts 2017-2021, number of individuals varying from 12 (2021) tot 51 (2018)	yes
Stichting Landschapsbeheer Gelderland	Gld	yes, but no GIS	10.0	yes	yes	yes, standardised partridge counts Sovon	no
WBE Aalten e.o.	Gld	no	?	yes	no?	adults and juveniles counted in 2012-2019 but area counted not given	no
IKL-Limburg	L	no	c. 2-2.5	yes	yes	yes, 2018-20	no
Natuurrijk Limburg	L	yes	2.7	yes	yes	yes, count data and demographic parameters, 2014-2020	yes
PARTRIDGE,Brabants Landschap	NB	yes	0.9	yes	yes	yes, standardised counts 2019-2021	yes
demo Struikwaard	NB	yes	0.04	yes	yes	yes, standardised counts 2012-2018	yes

Appendix 2 continued

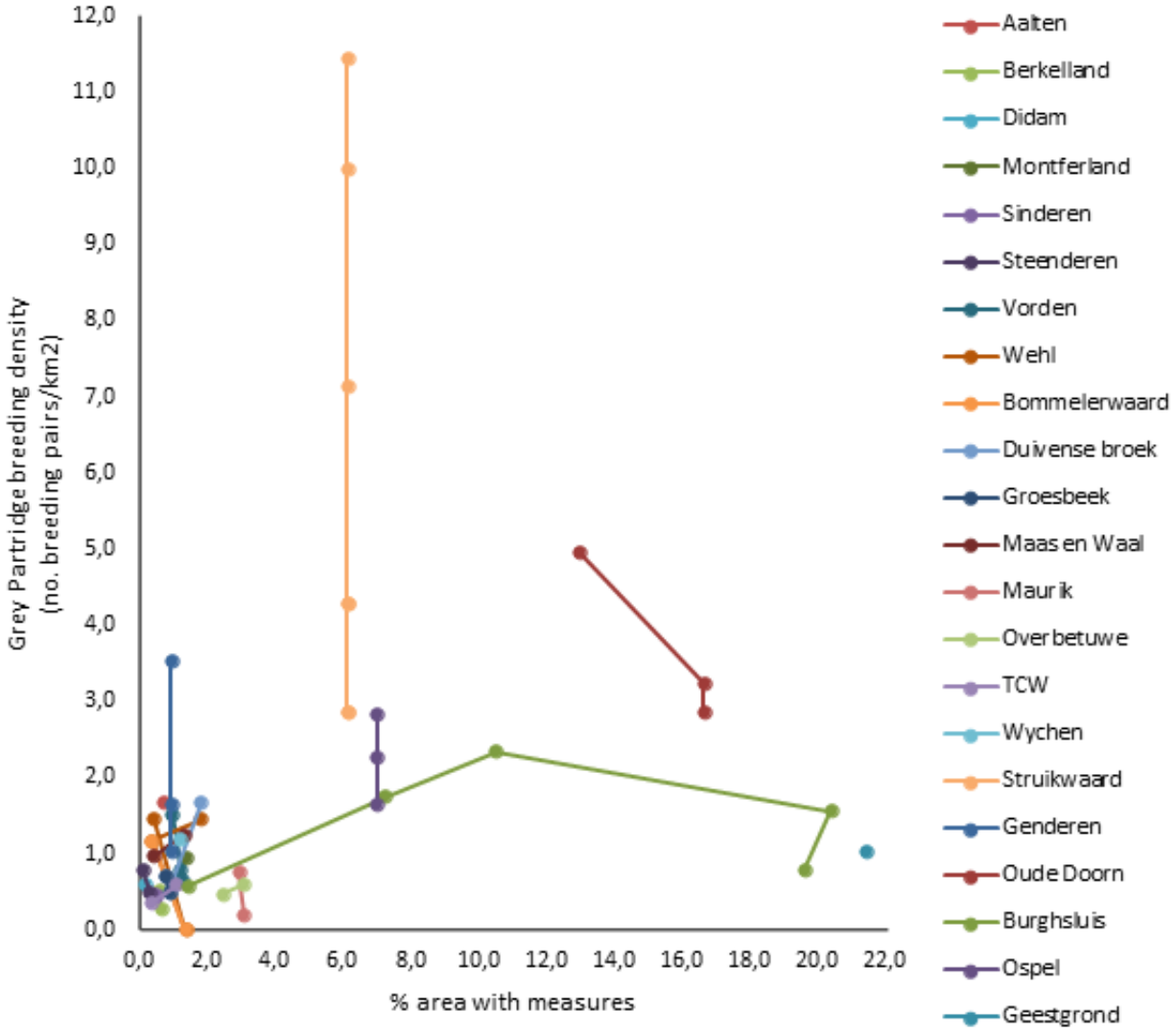

Figure A2.1. Grey Patridge breeding density and percentage of area covered with measures, both AES and other.

Appendix 2 continued

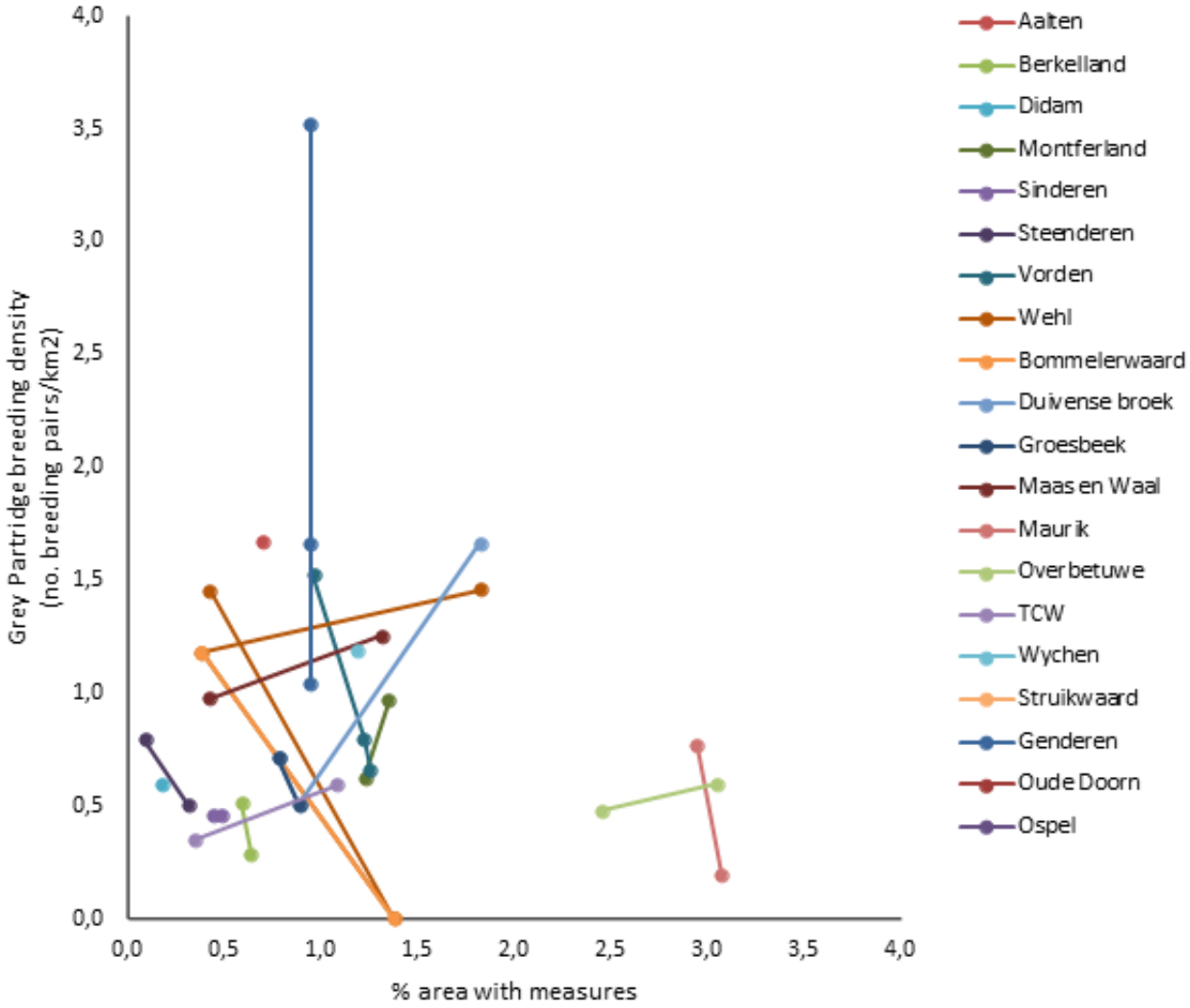

Figure A2.1a. Detail of figure A2.1, spanning the range from 0% to 4% of area with measures.

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