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Source: Wildlife Biology, 11(4) : 287-298

Published By: Nordic Board for Wildlife Research

URL: https://doi.org/10.2981/0909-6396(2005)11[287:GPPPPS]2.0.CO;2

Grey partridge *Perdix perdix* population status in central northern France: spatial variability in density and 1994-2004 trend

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Bro, E., Reitz, F. & Landry, P. 2005: Grey partridge *Perdix perdix* population status in central northern France: spatial variability in density and 1994-2004 trend. - Wildl. Biol. 11: 287-298.

The grey partridge *Perdix perdix* is an important management concern in the European farmland. Pair numbers severely declined during the 20th century. As a result, the species has been listed in SPEC category 3, i.e. 'Unfavourable' conservation status in Europe. The largest population of western Europe occurs in France. Its status there is, therefore, decisive for the European conservation status of the species as well as for the future of the species. Populations of partridges in central northern France have been routinely surveyed since the 1980s for hunting management purposes. In this paper, we use this long-term and wide-scale survey to portray the demographic status of partridge populations. We emphasise the amplitude of spatio-temporal variations in breeding densities. In the 2000s, a number of areas where agriculture is intensive and where the species is hunted still sustain > 50 pairs/km^2, whereas densities are < 5 pairs/km^2 in other areas. These low densities are, however, higher than those commonly reported from other parts of Europe. Density levels exhibit large differences at a small spatial scale and show large year-to-year fluctuations which make trend assessment difficult. The 1994-2004 and 1999-2004 trends displayed different patterns; densities increased, decreased or were stable depending upon agricultural region.

Key words: breeding density, France, grey partridge, Perdix perdix, spatial variability, temporal fluctuations, trend

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Article accepted for publication in Game and Wildlife Science (GWS) prior to the merger between WILDLIFE BIOLOGY *and GWS. Therefore, this article has not been peer-reviewed by* WILDLIFE BIOLOGY *Associate Editors*

Like many bird species associated with agricultural land (e.g. Siriwardena et al. 1998, Rocamora & Yeatman-Berthelot 1999), the grey partridge *Perdix perdix* has experienced a dramatic decline in Europe since World War II (Tucker & Heath 1994). According to Potts (1997), breeding stocks have dropped by > 80% since the 1930s. As a result, the grey partridge has been listed in SPEC category 3, i.e. 'Unfavourable' conservation status in Europe, but with main numbers outside Europe (Tucker & Heath 1994, Aebischer & Kavanagh 1997). Recently, BirdLife International (2004) drew attention towards this species because "although the species was stable or increased in many eastern European countries during the period 1990-2000, it has continued to decline throughout most of western and central Europe - including sizeable populations in France and Poland - and underwent a large decline overall". This decline is all the more worrying because agro-environmental schemes have been applied in most countries for the benefit of wildlife (see Kleijn & Sutherland 2003, Bro et al. 2004).

The European breeding stock of grey partridge (excluding the Russian and Turkish populations) was estimated at 1.7-2.9 million pairs in the mid-1980s (Aebischer & Kavanagh 1997), and at 1-2.3 million pairs in the 1990s (BirdLife International 2004) with the largest population occurring in France. Reitz (2003) estimated the breeding population size at ca 750,000 pairs in France in spring 1998. The status of the French population is, therefore, decisive for the overall European conservation status of the species as well as for the future of the species in western Europe.

In France the grey partridge is a culturally important gamebird. Within the sedentary small game species inhabiting cultivated plains, the grey partridge ranked fourth in number of individuals killed by hunting after pheasant *Phasianus colchicus*, rabbit *Oryctolagus cuniculus* and red-legged partridge *Alectoris rufa* (ONCFS 2000). Ca 1.5 million birds were shot during the 1998/99 hunting season (Reitz 2000), but the proportion of released birds in the bag was unknown. Tupigny (1996) estimated that two million grey partridges were reared in France in 1995. However releases are mostly practised in regions where the species has almost disappeared (Reitz 2003a). In central northern France, where the species is still well represented, progressive hunting management has been practised since the mid-1980s (see Reitz 2003a) to ensure sustainable hunting (Aebischer 1997) and to preserve wild birds. Within this context, a survey of partridge populations assessing breeding density and reproductive success is conducted annually (see Reitz 1999, Bro et al. 2003). The primary objective of this survey

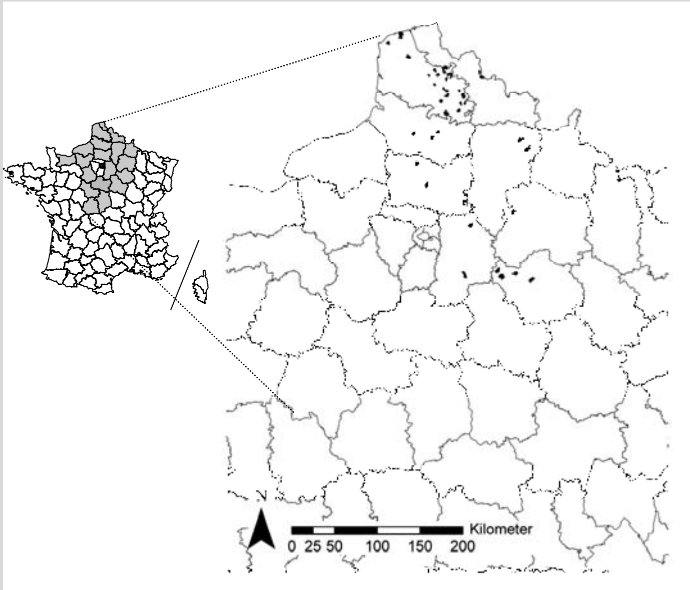

Figure 1. Central northern France with indications of the communes where counts were carried out in spring 1998, and where hand-reared birds were released for shooting purpose during the 1997/98 hunting season (from Reitz 2003a). The grey area shows the range where partridge populations were routinely surveyed and the black area shows Paris and its suburbs. See Figure 3 for the definition of French administrative divisions.

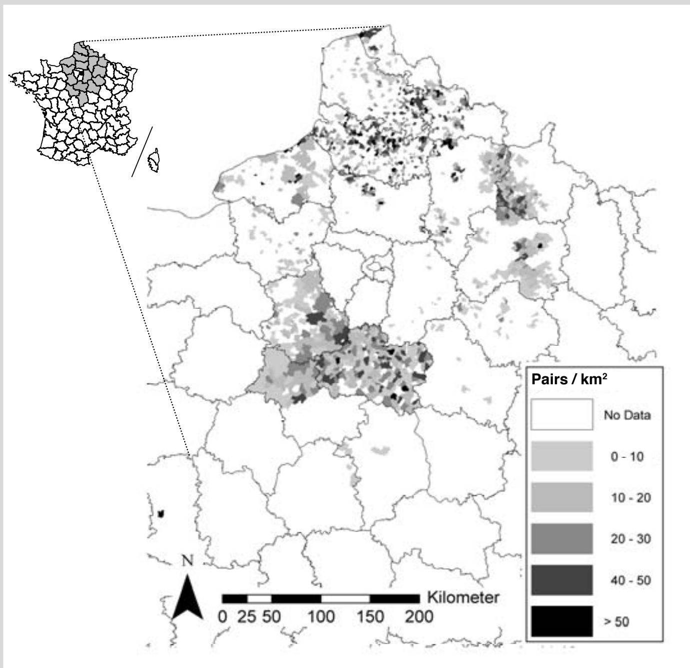

Figure 2. Breeding density (in pairs/km^2) of grey partridge populations at the commune scale in central northern France. Data are means from 2000-2002.

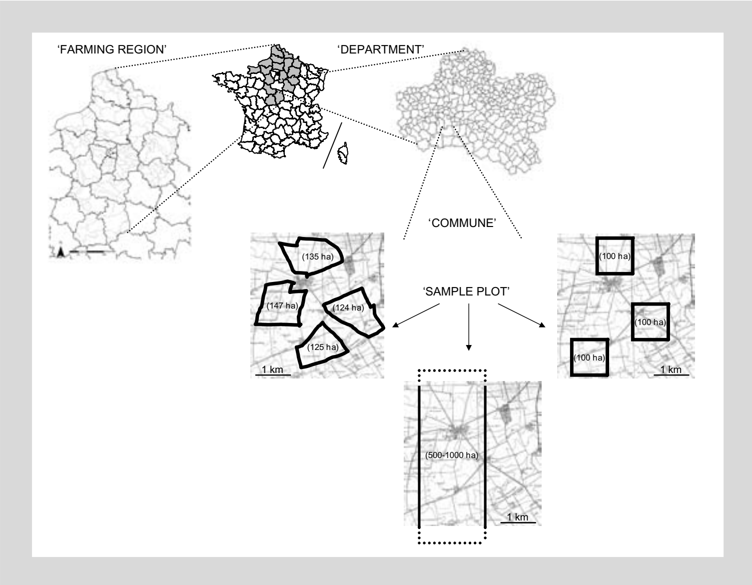

Figure 3. The administrative division of communes and departments. Communes are nested within departments. Farming region is another division, independent of department, pooling communes whose farming characteristics are similar. Counts were carried out in three different types of sample plots within communes; both were representative of the area.

is to calculate bag limits (quotas) to adjust hunting pressure to pair density and reproductive output at a local scale (Reitz 2003b).

In our paper, we use this long-term and wide-scale survey to portray the status of the grey partridge in central northern France, emphasising the large spatio-temporal variability. We present a map of 2000-2002 breeding densities at the 'commune' scale and assess both the 1994-2004 (long-term) and 1999-2004 (recent short-term) trends in densities for each 'farming region'.

Methods

Field procedures

The French national partridge survey

Monitoring of grey partridge populations was initiated in the early 1980s in a few areas and was progressively extended to many other areas in central northern France. Spring censuses and brood surveys have been conducted every year to assess breeding density and reproductive success (see Reitz 1999, Bro et al. 2003).

Because the primary objective of this survey is to calculate hunting bag limits, these areas correspond to hunting estates where hunting management is undertaken to manage wild grey partridge populations; only few of these hunting estates practised releases of a small number of hand-reared birds for shooting purposes (Fig. 1). Therefore these areas were not selected at random or using a particular sampling procedure. However, extensive counts are carried out in some farming regions, hence they correctly reflect partridge status (Fig. 2 & Table 1, and see the sections 'Statistical analyses' steps 3a and 3b and 'Discussion').

Spring counts

Spring censuses were carried out to estimate the breeding stock. Counts were performed in March, when birds had paired and before the crop cover was too high (in particular oilseed rape and winter cereal). We censused partridges that flushed from the sample plot while fields were beaten by a line of people (see Reitz 1999). To achieve a census as complete as possible, 20-50 people were needed to count one sample plot depending upon its area (ranging approximately within 80-250 ha). Sample plots were representative of the 'commune' (Fig. 3).

Spring counts were reported either as (i) the number of pairs, trios and single birds (where density levels were low) or (ii) the total number of birds. In the former case, the number of pairs was calculated as the number of pairs and trios plus the number of single birds divided by 2.1; in the latter case as the total number of birds divided by 2.1 (Reitz & Berger 1994). The number 2.1 corrects for the unbalanced sex ratio in spring (Birkan & Jacob 1988). The spring sex ratio was estimated in the field by examining pairs and single birds using binoculars.

Statistical analyses

We estimated the trend of breeding density as the regression slope of density (previously log-transformed) against year (continuous variable). We used an autoregressive error model to diagnose and correct for serial correlation due to time series (proc AUTOREG - first-order autoregressive error, maximum-likelihood method). Missing values in time series were not filled because the procedure permits embedded missing values for both the independent and dependent variables.

The statistical unit was the 'commune' (see Fig. 3); density level in the commune was the average of densities estimated on sample plots. Communes were pooled to estimate density trends in farming regions. Trends were estimated for both the 1994-2004 (long-term trend) and 1999-

Table 1. Levels of grey partridge density (pairs/km^2, mean ± SE) in each farming region of central northern France in 1994-2004. Proportions of the communes and arable land sampled were estimated using data from 2000-2004. This information is given to assess data representativity. The proportion of arable land censused is reported as classes because the area actually censused may vary from year to year.

		Communes		Arable land (ha)		Year										
Farming region	Code	N	% sampled	Total area	% counted	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Vignoble du Barrois	11	101	1	71043	< 1											5.8
Vallée de la Champ. crayeuse	13	46	6.5	44615	1 - 5			18.2	19.0	15.1±7.3	12.1±4.4	18.2±8.9	19.9±3.6		11.3±3.4	14.1±3.7
Pays de la Brienne	14	25	12	13352	1 - 5						3.0±2.4	4.1±2.6	7.5±1.0		4.5±0.8	6.4±1.7
Plaine de Troyes	15	31	9.7	19405	1 - 5			11.6±2.4	11.7±2.8	13.4±9.0	19.1±6.0	18.5±5.7	22.2±10.0		11.4±2.8	12.0±2.8
Vallée de la Marne	16+61	136	14.7	72126	10 - 20		4.0	7.5±3.5	17.6±2.4	14.2±2.1	18.5±2.3	20.5±2.7	20.4±2.4	21.7±3.0	28.5±7.0	28.2±3.0
Vignoble	17	52	7.7	24926	1 - 5					16.0	8.7	8.0±4.0	7.8±1.8	7.0±1.0	16.2±12.8	10.8±2.6
Pays Remois	18	41	31.7	31997	10 - 20							19.2±1.4	25.1±2.5	19.9±1.7	21.5±1.8	24.9±2.4
Vallée du Nogentais	19	8	25	5983	10 - 20			6.9±3.8	9.2±5.6	15.9±9.7	15.4±11.5	20.7±16.3	18.9±16.2		13.3±10.2	14.5±9.4
Ardenne	21	78	2.6	2187	.										27.4	30.1±3.6
Crêtes pré-ardennaises	22	219	17.8	124029	5 - 10			11.7±3.3	8.7±1.1	6.7±1.2	7.8±1.3	12.1±1.0	13.4±2.0	13.3±1.5	14.4±1.4	21.8±2.1
Pays d'Aire	23	57	24.6	26614	5 - 10		18.1±1.7	20.1±3.7	23.7±4.5	25.7±5.5	23.3±3.5	20.0±2.9	20.7±2.7	18.1±3.3	20.3±2.7	27.1±3.7
Collines Guinoises	24	25	8	13963	1 - 5			16.0±9.0	24.0±4.0	29.5±3.5	23.0±4.2		16.5±1.5	7.0	10.5±4.5	11.0±2.0
Flandre	25+325	129	11.6	115702	5 - 10		38.0±3.7	35.5±3.5	40.7±8.1	34.3±15.0	32.0±4.1	37.1±4.7	31.5±5.3	29.0±3.9	21.8±2.6	22.9±3.2
Région de Lille	26	95	6.3	28564	.			50.0			38.3±6.5		30.3±5.8	36.6±7.5	12.5±1.5	19.0
Pévèle	27	23	43.5	12063	10 - 20		30.0	29.4±5.8	38.5±6.2	27.5±3.8	33.9±5.5	50.3±12.5	40.2±5.6	40.3±5.7	36.1±6.9	22.1±2.5
Plaine de la Scarpe	28	86	19.8	28514	5 - 10		32.6±9.7	32.3±9.3	35.0±6.4	25.4±5.8	35.5±3.6	32.6±3.8	39.9±4.1	41.4±3.7	33.3±3.4	30.1±4.2
Boulonnais	29	83	20.5	41047	1 - 5		6.0	9.0	5.0	11.0	17.0±4.4	21.0	10.0±2.0	7.0	10.9±1.3	14.2±1.8
Artois - Cambrésis	30+326	433	23.1	233097	5 - 10		28.5±2.0	28.8±1.3	28.4±1.3	30.5±1.5	35.3±1.5	38.7±1.7	39.9±2.1	34.1±1.9	25.1±1.1	32.4±1.3
Béthunois	31	47	14.9	14839	10 - 20		30.1±8.1	20.6±7.9	19.4±4.7	21.5±6.2	23.3±9.6	30.0±14.7	24.5±7.1	13.5±5.5	17.5±5.5	15.4±1.4
Ternois	32	219	14.2	107235	5 - 10		19.4±1.9	21.9±2.1	20.9±1.8	20.4±2.2	26.7±2.1	31.2±1.7	28.1±3.0	36.3±2.5	23.5±2.5	27.4±2.0
Hainault	33	154	11	77653	1 - 5		23.4±3.7	22.5±2.0	19.9±2.1	20.0±3.1	27.2±1.6	34.5±1.9	30.9±2.5	36.5±3.9	29.4±2.6	32.4±3.5
Saint-Quentinois/Laonnois	34	250	22.4	185266	5 - 10				26.4±6.4	23.8±8.2		28.5±3.6	30.2±3.1	35.2±3.7	31.6±2.5	34.1±2.5
Santerre	35	242	28.5	134420	10 - 20	22.0±1.4	20.0±1.2	30.8±1.7	18.5±1.0	17.1±1.0	23.1±1.3	28.3±1.6	29.4±1.6	24.2±1.3	22.1±1.2	26.2±1.2
Ponthieu	36	126	35.7	84681	10 - 20	19.3±1.1	16.1±1.1	26.9±2.2	21.5±1.2	20.9±1.6	23.9±1.7	31.7±2.1	33.1±2.6	31.7±2.1	26.2±1.6	27.4±1.6
Marquenterre	37	12	8.3	11118	1 - 5	18.0±10.0	21.5±8.6	31.0±2.0	21.1±4.3	12.4±0.3	16.0	24.2±3.1	17.3±8.8	22.0	26.0	16.0
Vimeu	38	130	35.4	73318	20 - 30	20.7±1.4	15.5±1.3	24.7±2.1	17.5±1.1	16.3±1.4	20.5±1.3	28.3±1.6	28.1±1.7	28.3±1.7	25.9±1.7	26.7±1.8
Pays de Montreuil	39	80	7.5	44309	1 - 5		9.7±3.5	11.5±2.0	12.3±2.0	12.0±2.2	14.7±3.7	19.7±1.2	17.8±1.3	11.0±2.0	7.4±2.4	10.5±2.8
Pays de Thelle	41	60	1.7	31223	< 1						13.4		11.0	15.8		16.5
Clermontois	42	61	4.9	19195	1 - 5			2.4	10.0	6.4	10.6	10.0	16.5	11.8	10.4	11.8±1.9
Vexin	44+330	200	5.5	104640	1 - 5			10.0±0.0	6.7±0.4	5.5±0.0	9.7±3.0	9.4±2.2	7.1±1.1	6.7±0.9	9.0±1.5	15.6±3.7
Pays de Caux	46	409	24.2	210829	10 - 20	14.6±0.9	16.3±1.0	16.9±0.9	21.4±1.1	16.8±0.8	20.4±0.8	21.0±0.8	23.7±0.7			
Petit Caux	47	58	72.4	31569	70 - 80	20.9±0.5	18.4±0.2	25.5±0.7	24.3±0.6	18.2±0.3	18.8±0.3	21.8±0.5	26.7±1.0			
Entre Bray et Picardie	48	49	14.3	38613	1 - 5				11.0±0.0	14.3±1.8	17.6±0.0	17.7±0.0	13.3±1.0			
Entre Caux et Vexin	49	63	39.7	27566	10 - 20	21.0±0.0	18.1±0.0	24.3±0.8	32.9±0.3	28.3±0.3	23.8±0.4	33.2±0.7	22.9±0.7			
Roumois	52	71	8.5	33300	1 - 5	9.0±0.0	12.3±0.0	15.5±0.0				11.1±0.0	13.7±0.0	10.3±0.0	17.5±2.6	
Brie	58+335+336	348	9.2	256607	1 - 5	16.5±6.5	11.5±4.5	6.9±2.1	10.1±2.9	9.0±1.5	7.4±1.0	15.8±1.8	13.7±1.5	13.3±1.5	15.4±1.6	20.7±2.2

Table 1, continued

Farming region	Code	Communes N	Communes % sampled	Arable land (ha) Total area	Arable land (ha) % counted	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Montois	59	18	27.8	7888	20 - 30	18.0±5.0	11.8±0.3	16.3±4.8	17.8±11.3	19.0±13.0	20.9±5.4	21.8±6.3			28.1±3.4	39.5±5.9
Orléanais	63	42	42.9	30290	20 - 30	14.7±1.6	15.1±3.6	10.1±2.5	12.1±1.5	9.3±1.1	13.6±1.8	16.1±1.9	26.1±3.5	18.1±2.6	19.0±3.3	20.2±3.2
Pays de Bière	64	55	1.8	14122	1 - 5	19.0	17.0	14.5	12.0		13.0	15.0				
Val de Loire	67	41	80.5	28449	20 - 30	32.8±3.0	30.0±2.4	38.2±3.4	35.6±3.8	34.6±2.6	27.4±3.2	33.4±2.9	23.5±2.7	19.8±2.4	30.4±2.8	33.8±3.7
Perche	75+76+351	137	51.8	168179	10 - 20		15.5±1.4	14.4±0.7	16.0±0.8	11.7±0.6	12.0±0.7	11.3±0.7	8.1±0.7	7.8±0.5	9.4±0.7	10.7±0.8
Lieuvin	77	97	12.4	51951	1 - 5	11.0	14.0	25.0	18.6±1.0	12.6±0.4	18.0	14.8±5.8	13.1±0.7	10.9±0.3	14.6±2.5	21.7±1.8
Plateau de Neubourg	78	95	6.3	53616	1 - 5	11.0	14.0	18.0±7.0	10.8±1.0	9.5±0.6	8.5	9.0±0.0	7.7±0.0	8.9±0.1	8.5±0.7	8.9±1.3
Plateau d'Evreux St André	79	133	12	79575	5 - 10	8.8±0.7	6.8±0.3	10.1±0.7	13.5±1.1	10.0±1.0	12.0±1.4	14.6±1.4	11.2±1.3	11.3±1.2	11.5±1.3	16.2±1.9
Plateau de Madrie	80	38	7.9	14597	1 - 5	21.0	25.1	19.5	14.9±5.5	12.2±6.0	10.4±3.4	15.2±5.6	12.2±4.8	17.3±4.9	16.5±5.3	25.2±10.1
Plateau de Bourgogne	186	.	.	.	.			0.0					3.0±0.9		5.5±0.9	5.3±1.8
Argonne	315	58	1.7	35784	< 1										3.0	3.9
Champagne crayeuse	317	448	45.8	561767	10 - 20			9.0±0.7	10.2±0.5	7.6±0.6	11.1±0.8	16.4±1.0	17.6±0.9	17.1±0.9	19.0±0.9	21.7±0.9
Champagne humide	318	144	9	97042	5 - 10			8.6±0.8	6.0±1.8	4.1±1.0	3.7±1.1	4.7±1.2	4.7±1.4	5.4±2.5	3.4±0.7	5.5±1.2
Pays d'Othe	319	36	2.8	32242	1 - 5										9.4	11.5
Bassée et Basse Yonne	320	36	22.2	20709	10 - 20			4.7±1.3			28.5		5.5±0.7		25.8±5.7	37.8±12.0
Perthois	321	41	48.8	20366	10 - 20			3.5±2.2	7.5±1.0	6.1±1.0	7.3±1.1	6.5±0.8	7.5±0.7	6.5±0.9	9.4±1.2	9.5±0.9
Vallée de l'Yonne à la Marne	322	.	.			20.5	20.4	6.8±5.0	20.5	17.2	20.5	23.1	13.8±8.6	20.9	8.4	4.7
Thiérache	323	199	34.7	142390	5 - 10			11.5±6.5	30.9±27.1	6.8±2.2	15.0±6.1	13.9±1.1	16.7±1.3	19.8±1.4	23.2±1.5	30.2±1.7
Plaine de la Lys	324	42	19	35480	1 - 5		19.3±3.2	21.6±3.3	17.8±4.2	14.3±2.6	8.9±0.7	13.3±2.9	12.8±2.3	14.1±1.9	12.1±1.8	14.6±2.7
Plateau Picard	327	521	18	310082	5 - 10	21.0±1.2	16.9±0.9	21.8±1.2	19.9±0.8	17.8±1.0	27.6±1.2	31.5±1.4	31.1±1.7	31.7±1.3	29.1±1.1	31.6±1.1
Soissonais	328	278	10.1	85676	5 - 10			10.0		1.0		9.9±1.5	12.3±2.0	12.8±1.8	11.7±1.4	13.0±1.5
Valois	329	248	3.6	111667	1 - 5			7.3±0.7	15.8±3.0	19.2±4.8	6.0	27.6±8.1	27.0±6.0	27.0±7.1	25.1±5.7	27.8±3.6
Pays de Bray	331	162	25.9	107650	5 - 10	12.0±0.0	13.9±0.0	18.6±1.0	20.0±2.1	16.9±1.3	20.9±1.3	24.3±1.8	17.1±1.3			
Vallée de la Seine	332	150	2	35329	1 - 5	11.0	8.9	9.3±0.7	18.5±3.1	17.3±3.8	17.8±4.3	19.1±4.6	21.3±1.5	18.0	16.5	18.9
Drouais-Thymerais	334	105	49.5	75838	20 - 30		23.1±1.0	22.9±1.1	24.3±1.0	16.9±1.0	18.9±1.0	16.9±1.1	13.5±0.7	13.4±0.8	16.6±1.0	16.9±1.2
Gâtinais	338+339	203	40.4	189345	10 - 20	23.4±1.4	18.9±1.3	20.5±1.4	21.7±1.1	20.2±1.3	20.7±1.5	26.5±1.9	26.4±2.0	21.8±1.5	20.9±1.9	19.6±1.5
Puisaye	340	23	8.7	32715	1 - 5	12.3±3.5			9.9		4.7	5.1	32.6±6.3	28.6±6.1	2.7±0.5	3.4±1.5
Beauce	341+342	452	75.2	551862	10 - 20	22.4±1.3	22.3±0.7	22.7±0.6	24.6±0.7	18.2±0.5	21.4±0.5	23.3±0.6	20.4±0.6	18.4±0.6	21.2±0.6	17.9±0.5
Sologne	343	93	1.1	84228	1 - 5	34.5±11.1	21.3±3.4	30.9±4.2	26.3±5.0	31.5±7.2	22.9±1.3	29.0±6.1	31.2±3.6	19.8±2.4	22.4±3.9	22.3±3.9
Gâtine Tourangelle	346	22	100	26818	20 - 30			11.0±1.2	11.3±1.0	6.5±1.0	7.5±0.7	9.7±1.8	10.1±2.1	8.6±2.4	14.8±3.6	15.1±2.8
Vallée du Loir	350	27	100	18779	20 - 30			18.7±1.5	20.7±1.2	21.0±1.5	19.6±1.6	17.5±1.5	14.4±1.5	16.7±1.5	21.0±1.7	20.6±1.5
Pays d'Ouche	352	68	1.5	50961							3.8	3.0	6.6	6.0		
Pays d'Auge	353	246	0.4	12976							7.0	8.0			9.3	
Plaine Normande	355	201	7			6.0±1.4	5.9±1.9	7.2±1.7	9.4±2.2	9.9±3.0	12.0±3.1	17.3±4.4				
Champagne Berrichonne	434	189	5.8	208085	1 - 5		2.0±0.9	3.8±0.7	4.7±0.8	3.3±0.5	3.8±0.7	6.1±1.5		3.3±0.6	3.6±0.8	4.8±1.0
Sancerrois - Berry	439	48	8.3	80811	1 - 5	15.0±3.0	16.8±5.4		12.7±2.2		13.1±4.3	12.6±4.0	38.3±9.5	32.0±9.4	11.3±1.5	

Table 2. Trend in grey partridge density in each farming region of central northern France. See text for explanation about statistical analyses (full meta-analysis: step 2, resampling procedure: step 3). Results of the resampling procedure are given when the sign-rank test probability of the full meta-analysis is significant and/or when the number of communes is higher than 10.

	1999-2004 trend						1994-2004 trend					
	Full meta-analysis			Resampling procedure (100 iterations)			Full meta-analysis			Resampling procedure (100 iterations)		
Farming region code	N communes (≥ 5 years data)	Mean slope	Prob. (sign-rank test)	No communes	% of means with opposite sign	% of significant + marginally significant tests	N communes (≥ 8 years data)	Mean slope	Prob. (sign-rank test)	No communes	% of means with opposite sign	% of significant + marginally significant tests
16+61	10	0.040	0.130	4-10	2	2+2						
17	1	-0.152	/									
22	6	0.219	0.031	2-6	0	16+40	4	0.163	0.125			
23	5	0.040	0.812				5	0.043	0.125			
25	9	-0.076	0.027	3-9	0	6+2	2	-0.110	0.500			
27	1	-0.090	/				1	0.047	/			
28	9	-0.033	0.128				5	0.054	0.312			
30+326	38	-0.057	< 0.001	21-35	0	100	29	-0.002	0.941	17-28	17	0
32	2	-0.001	/				6	0.051	0.156			
33	6	0.035	0.062				6	0.069	0.031	2-6	0	1+1
35	31	-0.017	0.425	17-29	4	3	40	0.013	0.120	25-36	0	17+3
36	19	0.011	0.489	7-18	24	0	26	0.058	< 0.001	12-25	0	100
37	1	-0.008	/				1	-0.030	/			
38	23	0.027	0.166	12-22	0	4+4	28	0.061	< 0.001	14-26	0	100
39	2	-0.107	0.500				2	-0.007	/			
42	1	0.047	/				1	0.153	/			
44+330	10	0.088	0.160	4-10	0	3+1	3	0.085	0.250			
58+335+336	3	0.148	0.250				2	0.074	0.500			
59							1	0.056	/			
63	4	0.044	0.625				4	0.071	0.375			
67	15	0.044	0.151	7-15	1	11+3	21	-0.017	0.164	11-20	0	10+5
75+76+351	46	-0.025	0.033	27-43	0	31+6	54	-0.074	< 0.001	26-47	0	100
77	1	-0.105	/									
78							1	-0.055	/			
79	12	0.038	0.380	5-12	2	0+1	6	0.028	0.093			
80	3	0.140	0.250				1	0.021	/			
317	76	0.125	< 0.001	48-67	0	100	33	0.134	< 0.001	19-30	0	100
318	3	0.130	0.250				1	0.008	/			
321	8	0.132	0.039	3-8	0	2+1						
322							1	0.008	/			
323	1	0.145	/				1	0.159	1.00			
324	2	0.074	/				4	-0.038	0.125			
327	65	0.024	0.036	41-57	0	43+16	62	0.072	< 0.001	39-52	0	100
332	1	-0.080	/									
334	21	-0.018	0.479	9-19	9	3	57	-0.067	< 0.001	36-52	0	100

Table 2, continued

	1999-2004 trend						1994-2004 trend					
	Full meta-analysis			Resampling procedure (100 iterations)			Full meta-analysis			Resampling procedure (100 iterations)		
Farming region code	N communes (≥ 5 years data)	Mean slope	Prob. (sign-rank test)	No communes	% of means with opposite sign	% of significant + marginally significant tests	N communes (≥ 8 years data)	Mean slope	Prob. (sign-rank test)	No communes	% of means with opposite sign	% of significant + marginally significant tests
338+339	44	-0.042	0.009	26-40	0	72+15	50	-0.016	0.108	27-44	0	7+6
340	1	-0.024	/									
341+342	219	-0.029	< 0.001	149-182	0	100	245	-0.012	0.001	168-201	0	93+2
343							3	-0.026	0.250			
346	20	0.094	< 0.001	11-20	0	98+1	20	0.012	0.588	11-19	13	1
350	24	0.005	0.450	13-23	19	1	24	-0.019	0.272	12-23	1	2

2004 (recent short-term trend) periods, using communes with at least eight and five year's data, respectively.

Trend analysis was performed in three steps:

1: a regression was performed for each commune. Then we combined the results of these separate analyses in a file (farming region, commune, slope of the regression and standard error (SE), r-square of the model (r^2), length of the time series (N) and P-value testing whether the slope was null) to be analysed in step 2;
2: we conducted a meta-analysis for each farming region to test whether the distribution of the slopes was significantly different from zero (proc UNIVARIATE - sign-rank test because assumptions of parametric tests were violated);
3: a) because counts were not carried out in random areas (see the section 'Field procedures') and this may bias results, we tested the robustness of the meta-analysis result using a resampling procedure. A random sample of ca 75% of communes was drawn from a uniform distribution (if ranuni(-1) ≤ 0.75 then selected = 1 else selected = 0) for each farming region. The seed was the computer clock. A meta-analysis (step 2) was performed on the random sample;
b) we ran all of procedure 3a) 100 times using an iterative macrovariable.

All statistical analyses were performed using SAS/STAT software (SAS Publishing 1999).

Results

Range of breeding densities in 2000-2002

Breeding densities (of wild grey partridges) of > 50 pairs/km², and even exceeding 70 pairs/km², still occurred in central northern France in the early 2000s (see Fig. 2 and Table 1). However, in other areas, density levels were as low as a few pairs/km².

Spatial variability

The map of mean 2000-2002 breeding densities showed sharp contrasts in density levels at a small spatial scale (see Fig. 2). High density (i.e. > 50 pairs/km²) areas were not gathered in a core region but were scattered both in northern and southern regions (see Fig. 2 and Table 1).

Trend patterns

Trend patterns were contrasting across farming regions (Table 2). As for density levels, positive and negative trends were not geographically gathered, but distribut-

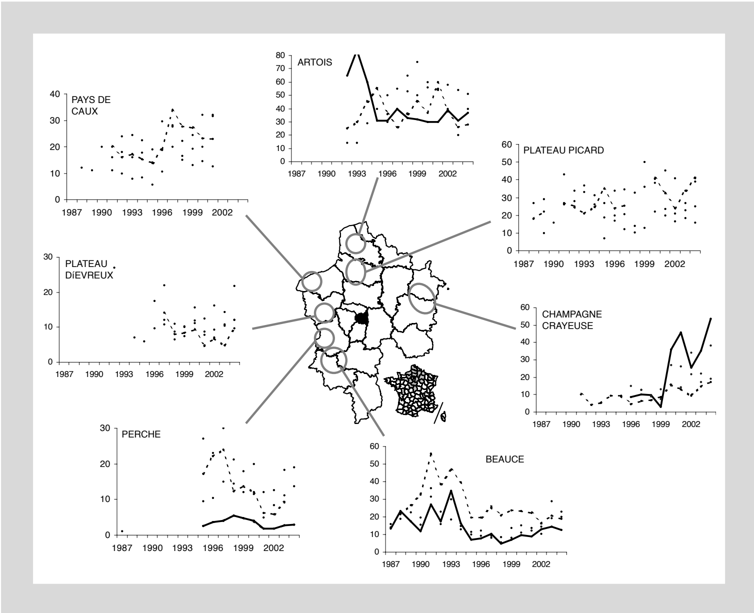

Figure 4. Examples of spatio-temporal variability in grey partridge density (in pairs/km^2). The lines refer to independent areas.

ed as a mosaic. However, few trends were statistically significant, either because the sample size (number of communes sampled) was low or because trends were not obvious due to large year-to-year fluctuations in density levels (Fig. 4 and see Discussion).

The four regions Ponthieu, Vimeu, Plateau picard and Champagne crayeuse showed an increase in partridge density in the long term. This result was driven by a recent increase in density for Plateau picard and Champagne crayeuse. Contrarily, partridge density decreased in the Perche and Beauce regions. Short-term and a long-term declines were observed in the Gâtinais and Drouais-Thymerais regions, respectively.

Discussion

Density levels

Density levels of grey partridge are very contrasting from one commune to another (and even at an infra scale; E. Bro, unpubl. data). Areas with densities as high as 50 or even 70 pairs/100 ha still exist in the early 2000s, whereas densities declined to a few pairs/100 ha in other areas. High and low density areas are spatially distributed as a mosaic at a small spatial scale, suggesting that high densities result from local, not global factors. However, environmental factors determining such variability is beyond the scope of this paper. Relationships between density and habitat characteristics were recently investigated at three nested spatial scales and a paper reporting results is currently in preparation.

The levels of density commonly found in France, not only high densities, are quite favourable compared to those frequently reported from other European countries (Table 3). The Polish partridge population that ranks second in size in Europe after the French population (Aebischer & Kavanagh 1997, BirdLife International 2004) sharply declined during the 1990s and densities reached an average of a few pairs/100 ha in many regions (Panek 2005). Densities as high as ca 20 pairs/km^2 or even exceeding 60 pairs/km^2 were recently reported as partridge 'hotspots' in suburbs of Praha (Salek et al. 2004) and Frankfurt (Kugelschafter & Richarz 2001). But these areas seem to be spatially restricted, and large city suburbs are not designated as long-term wildlife conservation areas.

Trends in numbers

Grey partridge numbers are reported to decline at the national scale. Reitz (2003a) estimated that the overall abundance of the species had decreased by ca 20% during 1979-1998. An other independent source of data in France reported a 49% decline of partridge numbers between 1989 and 2001 (CRBPO 2005).

Decline in numbers can result from an overall decline in densities or/and a range contraction. The decline of the grey partridge in France seems to be a combination of the two phenomena. This work did not allow range assessment because counts were carried out in areas where partridge densities were high enough to encourage hunters to survey and manage wild populations, but Reitz (2003a) documented this point comparing two inquiries. He reported a range contraction of the species in France between 1979 and 1998. The grey partridge has declined most in the Bretagne, Lorraine, Franche-Comté, Limousin, Auvergne and Rhônes-Alpes regions. The situation is more complex in central northern France where trend patterns were contrasting at the regional scale. Densities were roughly stable over the last decade in all but a few regions where densities either decreased (Perche, Drouais-Thymerais, Beauce) or increased (Ponthieu, Vimeu, Champagne crayeuse, Plateau picard). These findings are similar to Reitz's results using independent data sets (Reitz 2003a). Indeed, he found that the proportion of communes with densities of > 15

Table 3. Levels of grey partridge breeding density in some European countries and USA in the 1990s and 2000s.

Country	Spring density range (pairs/km^2)	Comments	References
Poland	1991-1995: 4-16	12 study areas throughout Poland	Panek & Kamienarz 1998
	2004: 0.4-8.3	10 agricultural areas (100-200 km^2 each) decrease of mean density in 1994-1998, stable in the 2000s	Panek 2005
Hungary	1993-1996: ca 1-5	4 study sites	Farago 1998
Czech republic	1990s: commonly < 5		Salek et al. 2002
	1997-1999: 24-33 at the south-west of Praha 2001-2002: local hotspots of 50-80	Praha suburbs	Salek et al. 2004
Austria	2001: 1-1.5	1 area	Klansek 2002
Germany	1992-1994: 1-9	Large population decline assessed through shooting bag	Kugelschafter & Richarz 2001
	1994-1995: 4-13	2 study areas (Bavaria)	Kaiser 1998
	Late 1980s: 0.19 (mean data) high density areas: 0.47	Partridges are spread all over East Germany but at very low density	Nösel 1992
Switzerland	mid 1990s: ca 10 pairs in 'Champagne genevoise'	Endangered population	Jenny et al. 1998
		Birds recently introduced	Buner et al. 2005
Greece	1995: 0.8-3.6 (high density areas: 6.4-12.3)		Papaevangelou et al. 2001
France	Late 1990s - early 2000s: from 1 to > 70	High spatio-temporal variability	Reitz 1999, 2003a, Figure 3
Italy	Late 1980s: ca 4	175-km^2 area in North Italy	Meriggi et al. 1985
		Precarious status, isolated small populations	Matteucci & Toso 1985
England	1970s: ca 12	Sussex study site	Potts & Aebischer 1995
	1988-1993: 4-5		GCT 2004
	2002-2003: ca 1		
	Demonstration site: 2.9 in 2002, 5.1 in 2003 Control site: 1.3 in 2002, 2.1 in 2003	Royston experimental site	GCT 2004
	2002-2003: 6-40 birds/100 ha in autumn	Partridge Count Scheme sites	GCT 2004
Ireland	1995 : < 100 pairs on 25 km^2	Endangered population	Kavanagh 1998
Finland	1992-1995: supposed < 2 because ca 4 birds / km^2 in winter		Turtola 1998
USA	1986-1992: 2-6		Rotella et al. 1996
		Range expansion since the three last decades in central Great Plains	Traylor et al. 2001

pairs/100 ha increased between 1979 and 1998 whereas the proportion of communes with densities of 6-15 pairs/100 ha decreased, but he observed an overall decline. These convergent results provide confidence in our conclusions (opposite trends depending upon regions). Yet the problem of low-density areas (few pairs/100 ha) persists. Indeed when partridge densities reach low levels, hunters lose their interest in the species because they cannot hunt it any longer (unless they release hand-reared birds for shooting purposes), and they often stop the survey. The other available methods to monitor partridge populations (survey using farmer's observations (Brun et al. 1990), prospection of linear features (Brun et al. 1990), presence of faeces (Pinet et al. 1981) or male call counts (Panek 1998)) are time-consuming and except the first one, they are not extensively carried out into practice. As a consequence, long-term surveys are biased towards high density areas (i.e. central northern France) and population dynamics at low density are little documented. Unfortunately, other monitoring programmes, such as the STOC (CRBPO 2005) or the ACT (Boutin et al. 2003) are not suitable for the grey partridge and thus can not complete our survey at the national scale.

We estimated trends in density performing a meta-analysis on regression slopes of log-transformed density levels against years. This procedure may nevertheless be questioned for species such as the grey partridge whose population dynamics are highly fluctuating from year to year (see Fig. 4). Our long-term survey showed that a number of areas sustained very high densities (> 70 pairs/km^2) only temporarily. Peaks often occur simultaneously in a number of areas (for instance Petit Caux in 1997 and Beauce in 1991; see Fig.

4) and are generally related to a good reproductive success the previous year (E. Bro, unpubl. data). A positive or a negative trend may result from such peaks when they occur at the beginning or at the end of the survey. Siriwardena et al. (1998) recommended the use of smoothed index series to solve the problem. We preferred to describe trend patterns providing the corresponding data (see Tables 1 and 2).

Management considerations

Together with other farmland birds, the grey partridge has been reported to be a species whose conservation status has worsened alarmingly (see BirdLife International 2004). Indeed, numbers have continued to decline over the last decade in western Europe despite the application of agro-environmental schemes in most countries (see Kleijn & Sutherland 2003). Moreover, the species is all the more exposed because it is huntable (listed on annex II of the Bird Directive). For all that, hunting is not necessarily the reason for the persisting decline. Sustainable hunting may be justified (see Ellison 1991, Aebischer 1997). Our survey of the grey partridge in farmlands shows firstly that high density wild populations still occur in intensively cultivated areas (cereal ecosystems where wheat yield may reach 120 Q/ha) where partridge hunting is culturally important. Secondly, it highlights that except in a few farming regions, densities did not particularly decline during the last decade but fluctuated from year to year. In most of central northern France, the species is likely to benefit from sustainable hunting in three ways:

- Hunting provides financial resources for scientific research (carried out by the governmental Game & Wildlife Agency, ONCFS). The population dynamics of the grey partridge are uniquely well studied among farmland birds. Research involves a large-scale and long-term survey (this paper), large-scale experiments (see Bro et al. 2004) and widespread field management (Bro et al. 2004). Understanding the cause of its decline allows scientists to make recommendation about conservation and agricultural management (see Potts 1997). Some management prescriptions were included in recent CAP reforms.
- Hunting management requires annual and local field data to attribute quotas to hunting estates, hence it provides long-term and wide-scale monitoring of partridge populations.
- Hunters invest time and effort in managing farmland habitats and controlling predator abundance to increase hunting bags. This land management favours partridge abundance and productivity (Tapper et al. 1996), and this often results in higher densities in areas where the partridge is hunted than in areas where the partridge is not hunted. This is what N. Aebischer named "the paradox of wise use" (Aebischer 1997). Such generic conservation actions are likely to benefit other farmland species, also.

In other parts of France where the species has declined to near extinction, hunters should resist the temptation to release hand-reared birds for shooting purpose while continuing land management in order to try to preserve the last wild birds.

Acknowledgements - the French 'grey partridge national network' is a collaboration between the Fédération Nationale des Chasseurs (FNC), the Fédérations Départementales des Chasseurs (FDC) and the Office National de la Chasse et de la Faune Sauvage (ONCFS). We acknowledge all field technicians of FDC and ONCFS and hunters who have been collecting the data for many years.

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