

Effectiveness of habitat management for improving grey partridge populations: a BACI experimental assessment

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Abstract

Effectiveness of habitat management for improving grey partridge populations: a BACI experimental assessment.— We assessed the impact of field division (4 m bare ground strips within wheat fields) and food supplementation (supplied through grain feeders) on grey partridge *Perdix perdix* L. populations using six-year 'before–after'/control–impact' (BACI) experiments. We did not detect any convincing positive effects of either of these two schemes on partridge pair density and reproductive success. Increases in pair densities were similar on managed and control areas, and contrasting results were found between some sites. No consistent pattern was observed between reproductive success and feeding intensity. Our studies highlight the need for field experiments at farm–scale to test the effectiveness of management measures. We conclude that, in the context in which they are applied, management techniques directed towards increasing partridge density do not systematically provide the desired outcome. We develop our point of view about management in the Discussion.

Key words: BACI experiments, Farm–scale, Grey partridge, Habitat management, Reproductive success, Spring density.

Resumen

Eficacia de la gestión del hábitat para mejorar las poblaciones de perdiz pardilla: una evaluación experimental BACI.— Evaluamos el impacto de la división de los campos (franjas de 4 m de suelo desnudo dentro de campos de trigo) y de la alimentación suplementaria (mediante suministradores de grano) sobre la perdiz pardilla *Perdix perdix* L., utilizando experimentos antes–después/control–impacto (BACI, 'before–after'/control–impact') de seis años. No detectamos ningún efecto positivo convincente de ninguna de estas dos medidas sobre la densidad de parejas de perdices ni el éxito reproductivo. Los aumentos en la densidad de parejas fueron similares en las áreas de control y en las gestionadas y se encontraron resultados contrastantes entre algunos emplazamientos. No se observó ningún patrón consistente entre el éxito reproductivo y la intensidad de la alimentación. Nuestros estudios destacan la necesidad de experimentos de campo en granjas, para comprobar la eficacia de las medidas de gestión. Nuestra conclusión es que, en el contexto en que se aplicaron, las técnicas de gestión dirigidas a aumentar la densidad de perdices no produjeron sistemáticamente el efecto deseado. En la Discusión desarrollamos nuestro punto de vista sobre la gestión.

Palabras clave: Experimentos BACI, Granja, Perdiz pardilla, Gestión del hábitat, Éxito reproductivo, Densidad primaveral.

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Introduction

The decline in grey partridge *Perdix perdix* L. populations after the Second World War has mainly been attributed to farming intensification and related loss of habitat quality (loss of crop diversity, field enlargement, scarcity of cover and food resources after harvest, etc., see the recent review of Kuijper et al., 2009). This is assumed to have led to a limitation in resources such as food and nesting sites. As a consequence, habitat management is often recommended to improve the carrying capacity of grey partridge on hunting estates. However, only a few studies have tested the effectiveness of the tools available for this on a wide scale.

From 2000–2007, we ran three projects examining the impact of various habitat management tools on grey partridge populations with the aim of having experimental verification, as well as, in case of positive results, demonstration sites for local hunting associations to motivate hunters and farmers to apply some management techniques more widely and intensively.

We separately assessed the effects of: (1) wildlife cover after cereal harvest, using maize–sorghum strips; (2) food supplementation, provided through grain feeders; and (3) dividing cereal fields, seeking to increase nesting cover within the cereal ecosystems, by using 4m bare ground strips to divide large cereal fields, using 'before–after'/control–impact' (BACI) experiments. We chose to examine these simple technical measures separately to dissociate their effect from the global effect of the usual package of management recommendations which combine habitat management, food supplementation and predator control.

The two first measures are currently commonly applied and the third one could reasonably be applied. In this paper, we report the results of the last two experiments; the first one has already been published in detail (see Bro et al., 2004). Hereafter we present the context of the studies.

Exp. 2. Food supplementation

Grey partridge densities vary from low (< 5 pairs/100 ha) to high (30–40 pairs/100 ha, or even more locally) levels in central–northern France (e.g. Bro & Crosnier, 2012; Bro et al., 2005; Mériau & Bro, 2009). In the late 1990s, we carried out an inquiry to identify and quantify the management techniques that were applied on managed hunting estates in this region (Mayot, 1999; 485 estates totaling 502,000 ha). Supplementary feeding appeared to be the most widely applied measure, occurring on 93.6% of estates. Other measures included plantation of hedges (on 41% of managed hunting estates, abundance varying between 3 and 1,600 m/100 ha); game cover (62%, < 0.10–ca. 10% of arable land), predator control (78.5%; judged as light on 22.5% estates, moderate on 28.4% and intensive on 27.8%). Furthermore, supplementary feeding was the only measure applied on a quarter of estates. The reason for this is that even though feeding is costly and time consuming, it can be easily applied by hunters who are not involved in farming the estate but are trying to improve habitat. Their ultimate aim

is to increase partridge stock in spring and improve reproductive success. The mechanisms involved are believed to be both a reduction in dispersal rates in late winter and the improvement of nesting hen condition. However, feeding appeared to be extensive with 40.4% of managed hunting estates with ≤ 5 feeders/100 ha and 76.4% with ≤ 10 feeders/100 ha. Such application of the measure raises the question of its effectiveness given it often does not match the rule of 'one feeder for one pair' (fig. 1A) that is commonly recommended, all the more that we did not detect a positive relationship. No relationship was detected with the reproductive success (fig. 1B). The objective of our study was to test the impact of a more intensive feeding regime (feeder density was ≥ 20 feeders/100 ha on 5.3% of the 485 estates) than that routinely applied on managed hunting estates across France.

Exp. 3. Field size division

The context of this experiment was quite different from the previous study. Hunters of an estate were applying the recommended partridge conservation measures, combining feeding, habitat management, predator control and limitation of hunting bag. Despite the fact that partridge density was higher on their estate than on surrounding estates, they considered it could be even higher. A limited nesting carrying capacity was a possible explanation. As these hunters were also farmers, they accepted to divide their fields of cereals as a further habitat management strategy. Cereal edge near a lane is the preferred nesting habitat of the grey partridge in cereal ecosystems in France (Bro et al., 2000a; Reitz et al., 2002) and the habitat where most nests survive (Bro et al., 2000b). The willingness of these farmers to increase partridge density on their farms offered us the opportunity to test the effects of a measure that had only been examined indirectly previously, by comparing contrasting natural situations (see Bro et al., 2008).

Methods

Study sites

The studies were carried out in the Beauce region, near the cities of Chartres (field size reduction experiment) and Orléans (supplementary feeding experiment). The Beauce region was the species' core area in the 1980s, but partridge densities here experienced a marked decline during the 1990s and 2000s (see Bro et al., 2005; Mangin, 2009). Crop cover consisted of approximately 60% of cereals, 15% of sugar beet and ca. 5–10% of rapeseed and maize. Peas, sunflower and potatoes were the other cultivated crops. The landscape was typical of the region, with open fields separated by some groves but almost no hedges. Satellite maps are available at e.g. <http://www.maplandia.com>.

Population survey

Spring censuses were carried out to estimate the grey partridge breeding stock. Counts were performed in

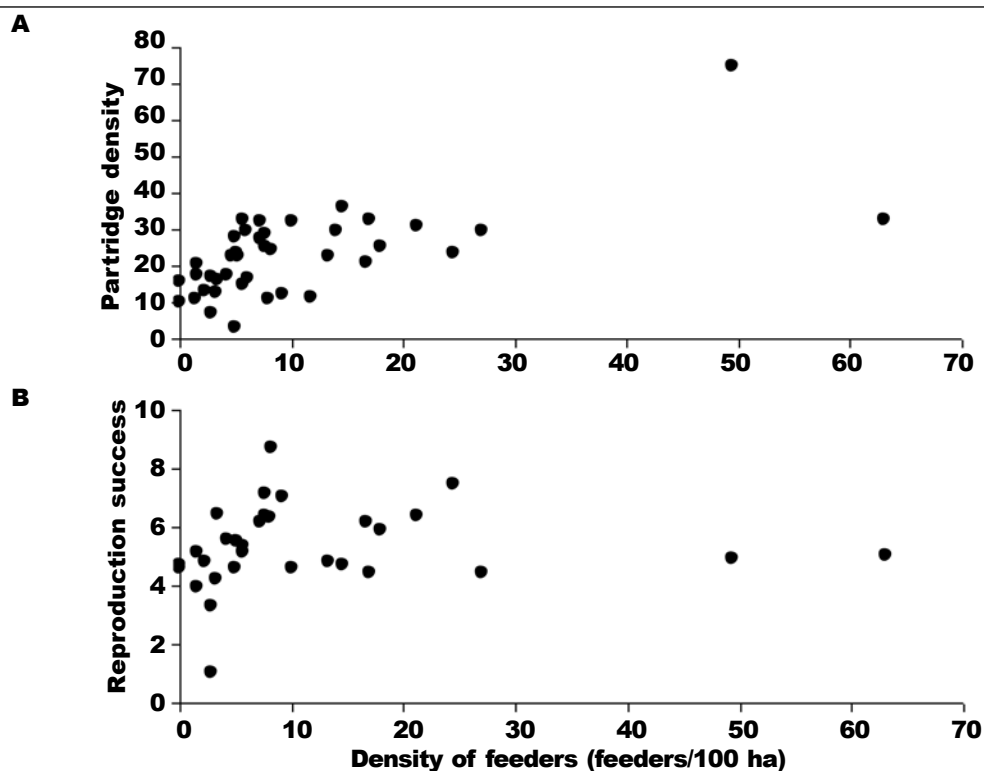


Fig. 1. Relationship between feeder density and: A. Partridge density (pairs/100 ha); B. Reproductive success (offspring/female) across managed hunting estates. (Unpublished data from wild populations in central–northern France.)

Fig. 1. Relación entre la densidad de alimentadores y: A. Densidad de perdices (parejas/100 ha); B. Éxito reproductivo (crías/hembra). (Datos no publicados de las poblaciones salvajes en el centro septentrional de Francia .)

March, when birds had paired and before crop cover was too high. The census was obtained by counting the number of partridges flushed while fields were beaten by a line of people (units called 'beats'; fig. 2). A full description of the field procedures is given in Bro et al. (2005). The same method was used on all sites, all areas (experimental and control), and all years.

Exp. 2. Supplementary feeding experiment

The experiment was replicated on two sites of 420 ha ('Oison') and 990 ha ('Bougy–Neuville'). Cereals crops amounted to 70% and 65% of arable land, respectively; rapeseed 15% and 14%, maize < 1% and 6.4%, permanent meadows 0% and 3.8%. Intensive feeding started in autumn 2003 and finished in autumn 2006. Feeding occurred from September to June. Feeders were mostly located along lanes; sometimes between wheat and sugar beet or maize fields. The density of feeders ranged locally between 10 and 50/100 ha across the experimental area, depending upon partridge density on beats in spring 2003 (with the rule of ca. 1 feeder/bird). On Oison, we increased mean feeder density 7 fold (from 6.1 to 43.6 feeders/100 ha, $n = 177$ during the experiment).

On Bougy–Neuville, it was increased by 2.6 (from 7.7 to 20; $n = 193$). Thus we tested the effects of an increase in feeding intensity, compared to the baseline application of the measure. Feeders were static during the course of the study and their number did not change. The total use of wheat grain was roughly estimated to 11–12 T/ year. The experiment cost ca. 10 k€.

Exp. 3. Field size reduction experiment

It was only possible to carry out this experiment on one site of 600 ha ('Aubepine'). As explained in the Introduction, the site was not chosen randomly. The area of winter wheat amounted to 53% of arable land and winter barley 9%. Mean field size of winter wheat was ca. 10 ha (12 ha in 2003, 9 ha in 2004 and 10 ha in 2005), varying from 3 to 41 ha (see a map in Mayot et al., 2009b). The experimental site was managed for partridges and pheasants. Wildlife set–aside was planted on 5% of arable land and bushes on 1%. In autumn, the hunting bag varied from 7 to 15 partridges/100 ha depending upon partridge density and reproductive success; it was achieved through 1 or 2 hunts. Legal predator control limited the number of red foxes, stone martens, carrion crows and magpies on

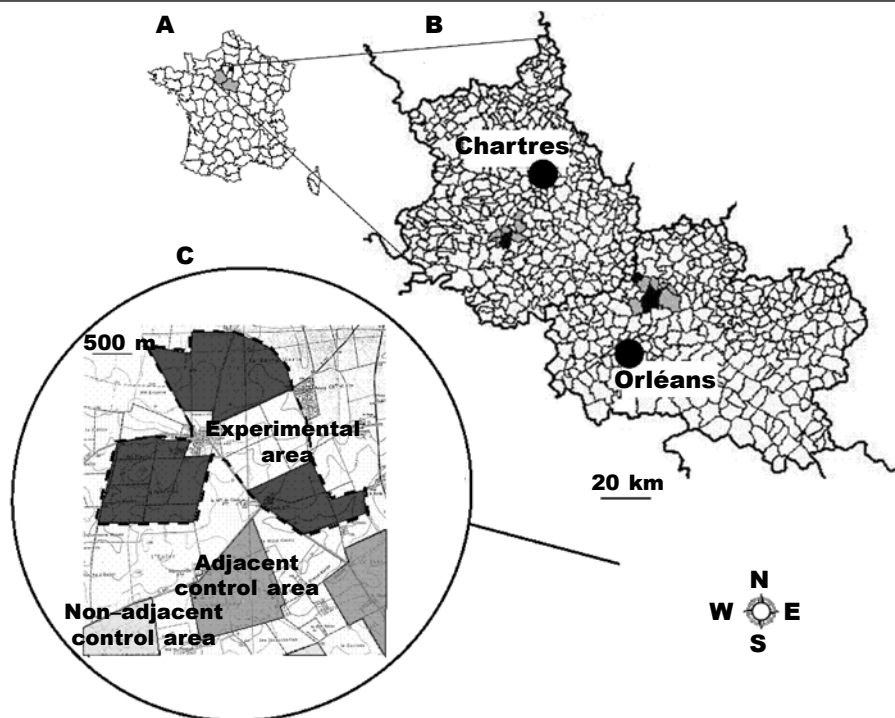


Fig. 2. Location of study sites within: A. France; B. Relative location of communalities with experimental (black) vs. control (grey) areas; and C. Spatial design of beats (ca. 80–150 ha) where censuses are carried out. In the example of Oison (C), the dotted line represents the limit of the experimental area, monitored through three beats. Adjacent beats are in dark grey and non-adjacent beats in light grey.

Fig. 2. Localización de los lugares de estudio: A. Francia; B. Localización relativa de las comunales con áreas experimentales (en negro) vs. áreas de control (en gris); C. Diseño espacial de las batidas (aprox. 80–150 ha) donde se llevaron a cabo censos. En el ejemplo de Oison (C): la línea de puntos representa el límite del área experimental, que fue monitorizada mediante tres batidas. Las batidas adyacentes están en gris oscuro, y las no adyacentes en gris claro.

the site (bag not available). Wheat grain was provided through ca. 100 feeders.

We collaborated with local farmers to reduce the overall size of winter wheat fields by using 4 m strips of bare ground to divide the fields. We tested strips of bare ground rather than strips of game cover because it is a simple technique which did not require any additional farming operation since they contained no cover. As the strips corresponded to an area where the grain was not sown they were managed in the same way as the crop except for insecticide and fungicide spraying. Strips were not located in winter barley fields because, in this region, this crop is harvested in late June, coinciding with chick hatching. Approximately 20 strips were introduced (23 in 2003, 24 in both 2004 and 2005), corresponding to a total area of 3 ha (3.291, 3.266 and 2.973 ha in 2003, 2004 and 2005, respectively) and a total length of 8 km (8.80, 8.87 and 7.82 km). The mean size of winter wheat fields during the experiment was reduced by 1.5 (data of 2004). The location of strips varied from year to year depending upon crop rotation. These strips represented

an additional abundance of wheat margins of 60 m/ha of winter wheat (61.5, 77.8, 58.5 m/ha). The increase amounted to 20% of the initial level. A compensation of 762 € / ha was paid both for yield loss and the lack of CAP subsidies. The total cost amounted to 7.3 k€ for the 3 years.

Experimental design

To test the impact of a given management scheme as rigorously as possible, we conducted 6-year 'before-after/control-impact' (BACI) experiments. We used the BACI design to attempt to overcome the problem of ascribing changes to the scheme rather than natural variability. We replicated the study over 2 sites where possible and used several control areas to provide further robustness to our results, allowing spatial heterogeneity to be taken into account.

Control areas were neighbouring areas (< 10 km, see fig. 2) so that habitat characteristics, weather, and predator abundance were assumed to be reasonably similar. Experimental and control areas were included in

Table 1. Intensive feeding experiment: spring density (pairs/100 ha) in 2000–2003 (period 'before') and 2004–2006 (period 'after') and difference (%) between the two periods.

Tabla 1. Experimento de alimentación intensiva: densidad primaveral (parejas/100 ha) en 2000–2003 (periodo "anterior") y 2004–2006 (periodo "posterior"), y diferencia (%) entre los dos periodos.

	Area (ha)	Before 2001–2003	After 2004–2006	% difference before/after
Site 1: Oison				
Experimental area	420	16.5	24.5	+48.5
Adjacent control area	260	11.9	23.7	+100
Non-adjacent control area	500	16	11	-31.3
Site 2: Bougy-Neuville				
Experimental area	990	11.7	25.9	+121.4
Adjacent control area	320	9.8	17.7	+80.6
Non-adjacent control area	820	10.8	27.7	+156.5
Other control areas (neighbouring municipalities of the same GIC)				
Saint-Lyé	500	11.5	20.4	+77.4
Santeau	490	14.6	31.5	+115.8
Aschères	640	15.8	21.2	+34.2
Chilleurs	620	14.6	16.8	+15.1
Crottes	580	22	36	+63.6
Montigny	370	16.1	26.8	+66.5

the same 'GIC' (*i.e.* grouping of several hunting estates to share a same game management scheme over an area of several thousands of ha), so that the baseline management could be considered as reasonably similar as well. It has not changed during the course of the studies, except for the manipulated factor on the experimental area.

We distinguished two kinds of control areas in the feeding experiment depending upon whether beats were adjacent (boundaries < ca. 300 m) or not to the experimental area (see fig. 2). The tables also provide data of partridge density on all surrounding municipalities from the same GIC where partridge populations have been routinely surveyed on a long-term basis. Field data of these additive control areas were extracted from the database of the national grey partridge population survey (see Bro et al., 2005).

Data analysis

Experiments were carried out on a large scale, and although we tried to replicate them (as we did for the 'cover' experiment), available data did not allow us to reasonably use the same statistical tests as in Bro et al. (2004). Instead we tested the relationship between the mean density or the mean reproductive success and the period ('before' vs. 'after') * area ('experimental' vs. 'control') interaction using an ANOVA (proc GLM, type III, SAS Institute). Year and area were included

as co-variables. Reproductive success was tested against the intensity of feeding (feeder-to-pair ratio) during the 'after' period using a glm with year and beat as co-variables (proc GLM).

Results

Impact of intensive feeding on spring density

On Oison, we observed an overall increase in densities on the 'feeding' area (table 1, fig. 3A). The rate of increase was higher than that observed on 3 of the 8 control areas. Statistically, this increase was not related to intensive feeding ($P = 0.520$). The pattern was quite different on Bougy-Neuville where feeding was twice as intensive (table 1, fig. 3B). Mean partridge density was stable from 2001 to 2004 and increased notably in the last two years, *i.e.* with a time lag of one year after started feeding (fig. 3B). Qualitatively, the same pattern was observed on both the adjacent and the non-adjacent areas (fig. 3B). Quantitatively, the increase rate was higher on the non-adjacent control area and lower on the adjacent area (table 1), but overall the difference was not statistically significant ($P = 0.741$). In addition, similar increases were observed in the other control areas (table 1). No significant correlation was found at the local scale between the reproductive success and feeding intensity ($P = 0.109$, fig. 4).

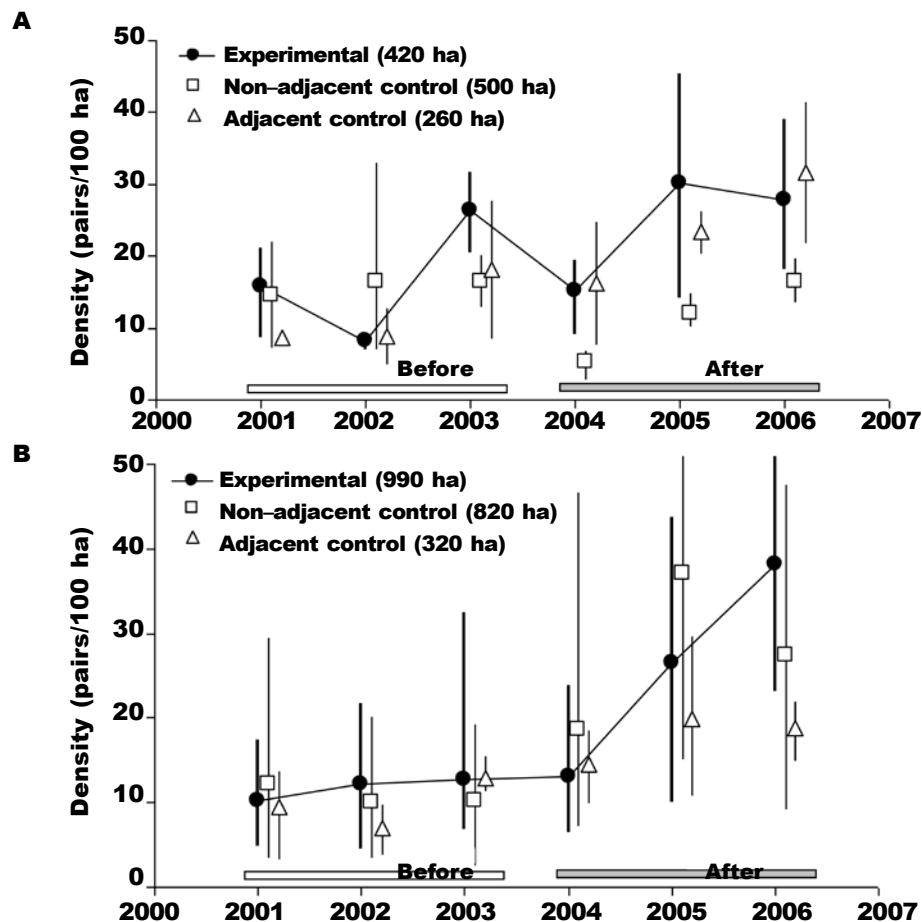


Fig. 3. Intensive feeding experiment: changes in spring pair density depending upon whether intensive feeding is undertaken or not, in the managed vs. control areas. Vertical bars indicate min. and max. values of densities recorded across beats; they are provided to describe spatial variability: A. Oison; B. Bougy-Neuvville.

Fig. 3. Experimento de alimentación intensiva: cambios en la densidad primaveral de parejas, dependiendo de si se ha llevado a cabo la alimentación intensiva o no, en las áreas de gestión vs. las áreas de control. Las barras verticales indican los valores mínimos y máximos de las densidades registradas mediante las batidas; se han incluido para describir la variabilidad espacial: A. Oison; B. Bougy-Neuvville.

Impact of wheat field size reduction on spring density

We observed an increase in pair density in 2003–2005 compared to 2000–2002 in both the experimental and the control areas (table 2, fig. 5A), and this was not be attributable to our experiment ($P = 0.562$). No differential effect was detected on reproductive success ($P = 0.403$, fig. 5B). Unfortunately, we were unable to replicate our experiment at other sites.

Discussion

Our three experiments testing the impact of wildlife cover (Bro et al., 2004), intensive feeding (see further technical details in Mayot et al., 2009a) and field size division (Mayot et al., 2009b) did not provide

convincing, definitively positive effects in the short term. Perhaps the limiting factors on our study sites were not food and nesting sites. Our experiments coincided with several years of good grey partridge reproduction throughout France (see Reitz & Mayot, 2009), which might have contributed to our inability to identify any positive effects. However, from the great body of research that has been dedicated to this species, it is well known that partridge populations are influenced by multiple external (*i.e.* environmental) and intrinsic (*e.g.* density-dependence) factors that are likely to vary in space and time and to depend upon population status. Hence, several mechanisms might explain our results but we have so far not been able to identify them. Therefore, we do not conclude that the measures we experimentally tested are inefficient but that, applied in the context described above, they

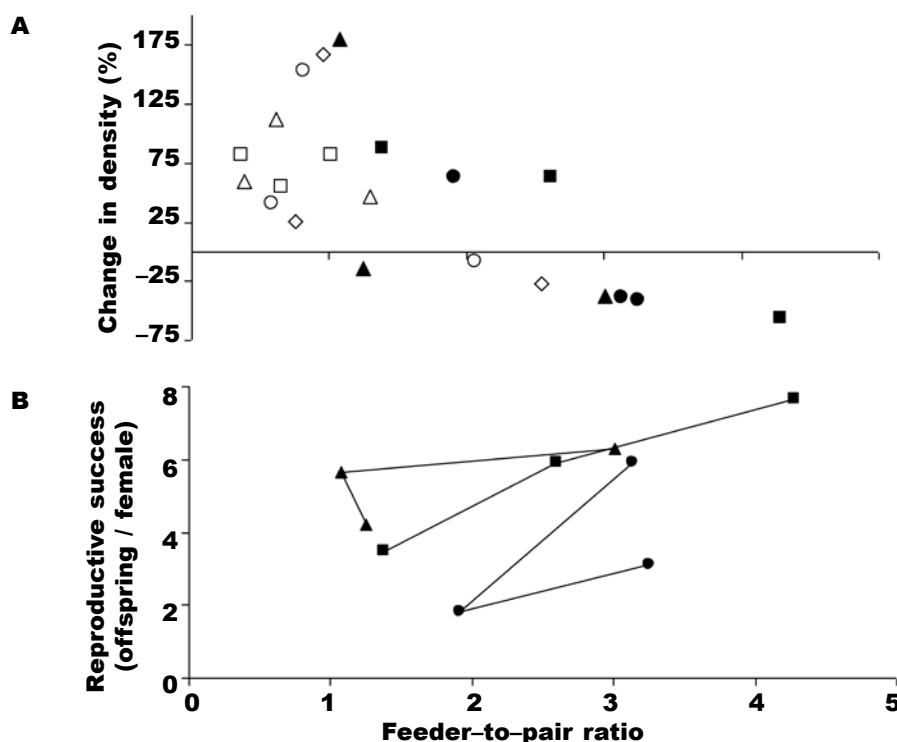


Fig. 4. Intensive feeding experiment: relationships between the changes in spring pair density (A) and the reproductive success (B) and the feeder-to-pair ratio during the three years of the 'after' period. Oison, black-filled symbol; Bougy-Neuville, open symbols. Each symbol corresponds to a separate beat. Note that coveys were not mapped on the Bougy-Neuville site so that figure B could not be drawn.

Fig. 4. Experimento de alimentación intensiva: relación entre los cambios de la densidad primaveral de parejas (A) y el éxito reproductivo (B) y la tasa de alimentador-pareja durante tres años del periodo "after", después. Oison, símbolos en negro; Bougy-Neuville, símbolos en blanco. Cada símbolo corresponde a una batida distinta. Nótese que no se mapearon las nidadas en el emplazamiento de Bougy-Neuville, de forma que no pudo dibujarse la figura B.

did not improve populations. This is compatible with previous experiments carried out at an individual level using radiotracking, which also moderated the impact of feeding on survival and reproduction, showing positive, negative or no effects (e.g. Haines et al., 2004; Hoodless et al., 1999; Townsend et al., 1999;

Valkeajärvi & Ljäs, 1994). In other words, our feeling is that all efforts do not always guarantee results. An important message we convey to hunters is to make a preliminary diagnosis of the characteristics of their estates to identify their actual weaknesses and then to focus on measures to counteract these (Bro

Table 2. Field size reduction experiment (for more details see table 1).

Tabla 2. Experimento de reducción del tamaño del campo (para más detalles ver tabla 1).

	Area (ha)	Before 2000-2002	After 2003-2005	% difference before/after
Experimental area	600	23.3	31.7	+36.1
Non-adjacent control area (same GIC)	1110	10.6	20.6	+94.3
Other control area (neighbouring GIC)	1800	9.5	12	+26.3

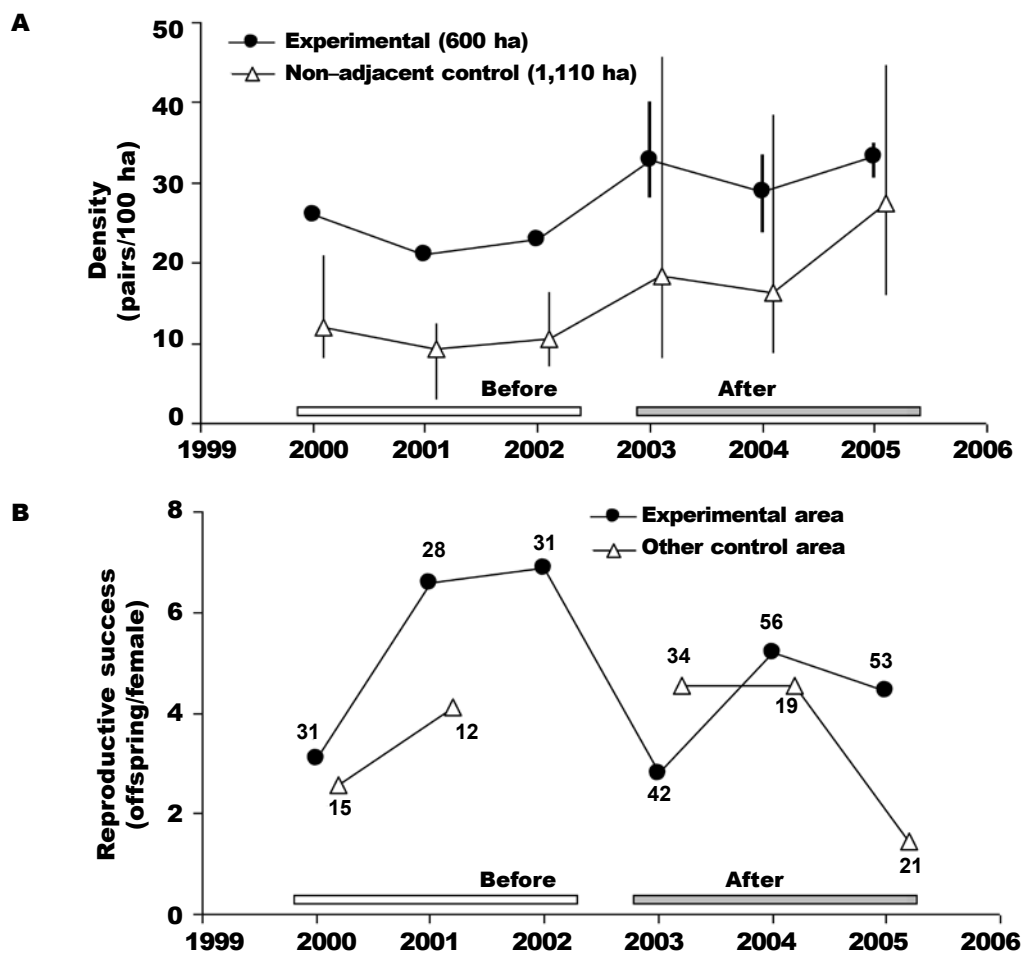


Fig. 5. Field size reduction experiment: A. Changes in spring pair density depending upon whether intensive feeding is undertaken or not, in the managed vs. control areas. Vertical bars indicate min. and max. values of densities recorded across beats; they are provided to describe spatial variability; B. Reproductive success during the course of the experiment on the experimental vs. other control area. Figures indicate covey numbers.

Fig. 5. Experimento de reducción del tamaño del campo: A. Cambios en la densidad primaveral de parejas, dependiendo de si se ha llevado a cabo la alimentación intensiva o no, en las áreas de gestión vs. las áreas de control. Las barras verticales indican los valores mínimos y máximos de las densidades registradas mediante las batidas; se han incluido para describir la variabilidad espacial; B. Éxito reproductivo durante el transcurso del experimento en el área de experimentación vs. área de control. Las cifras indican el número de batidas.

et al., 2009). We encourage hunters to improve the characteristics of their estates step by step, learning from a trial and error approach. Several partridge restoration programs have provided very good results (e.g. Mérieau & Bro, 2009; Connor & Draycott, 2010). This should encourage other hunters. A fully integrated management programme—including predator control, feeding and habitat management—was applied in these cases. The ultimate question is to what extent this can be done over a wide area and over the long term.

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