# Dynamics of the population of Common quail males in the island of Majorca and comparison with the northeast peninsular populations

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DYNAMICS OF THE POPULATION OF COMMON QUAIL MALES IN THE ISLAND OF MAJORCA AND COMPARISON WITH THE NORTHEAST IBERIAN PENINSULA POPULATIONS. The population dynamics of the common quail males in Majorca were studied through censuses and captures during two reproductive cycles (2017 and 2018). Results were compared with those obtained in a monitoring program of 13 years (2005-2017) that had taken place in two sites in the northeast of the Iberian Peninsula (Figuerola del Camp in Tarragona, and Alp in Girona). The aim of the study was to investigate the migratory status of the Majorca population and its possible connectivity with other adjacent populations. Being a game species, the knowledge of the phenology and population dynamics throughout the reproductive cycle allow suitable management and conservation. The temporal pattern of abundance of the quail found in Majorca was different from that of the continental populations. A very early phenology of breeding individuals, similar to that found in latitudes of the south of the Iberian Peninsula, suggests the possible winter stay of a fraction of the population in this island. On the other hand, a very delayed phenology in the presence of breeder yearlings suggests an isolation of the Majorca population in relation to the one that breeds in the continent. The lack of synchronization between the abundance pattern of the breeding stock and the cereal cycle, raises more detailed studies on the possible effects this may cause in the population.
***Key words:*** *Sedentariness; Phenology; Migration; Coturnix coturnix.*

DINÀMICA DE LA POBLACIÓ DE GUÀTLERA A L'ILLA DE MALLORCA I COMPARACIÓ AMB LES POBLACIONS DEL NORD-EST DE LA PENÍNSULA IBÈRICA. Es va estudiar la dinàmica poblacional dels mascles de guàtlera a Mallorca a través de censos i captures durant dos cicles reproductors (2017 i 2018). Els resultats es van comparar amb els obtinguts en un seguiment de 13 anys (2005-2017) que havia tingut lloc en dos localitats del nord-est de la península Ibèrica (Figuerola del Camp a Tarragona, i Alp a Girona). L'objectiu del treball va ser indagar l'estatus migratori de la població mallorquina i la seva possible connectivitat amb altres poblacions adjacents. En tractar-se d'una espècie cinegètica, el coneixement de la fenologia i dinàmica poblacional al llarg del cicle reproductor permeten una adequada gestió i conservació. El patró temporal d'abundància de la guàtlera trobat a Mallorca va ser diferent al de les

poblacions continentals. Una fenologia molt primerenca d'individus reproductors, similar a la trobada en latituds del sud de la península Ibèrica, suggereix la possible permanència hivernal d'una fracció de la població en aquesta illa. Per altra banda, una fenologia molt endarrerida en la presència de joves reproductors nascuts dins l'any suggereix un aïllament de la població mallorquina en relació a la que cria al continent. La manca de sincronització entre el patró d'abundància dels efectius reproductors i el cicle del cereal, planteja la realització d'estudis més detallats sobre els possibles efectes que això pugui provocar en la població.
***Paraules clau:*** *sedentarització; fenologia; migració; Coturnix coturnix.*

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## Introduction

The abundance of a species varies throughout a breeding season because of demographic parameters such as birth, mortality, immigration and emigration (Begon *et al*., 1988). These parameters respond to environmental and biotic factors and, therefore, can vary enormously within the distribution area of the species (Piñol and Martinez-Vilalta, 2007), so that their study can identify to which of these factors the population responds in a certain place.

If a species is migratory, the study of the dynamics of the population throughout its biological cycle allows, in addition, to know the moment in which it arrives at the place of reproduction, how long it remains in it and when it leaves towards the winter quarters (Sardà-Palomera *et al*., 2012). It must be taken into account that the migratory condition may be restricted to certain individuals, a phenomenon known as partial migration, in which part of the population migrates (migrating individuals) while another part resides throughout the year in the breeding area (resident or sedentary individuals, Dingle, 2014; Meller *et al*., 2016). This phenomenon can occur in breeding areas whose habitat allows individuals to be kept during the winter, but always in lower abundance than during the breeding season (Newton, 2008); this can, therefore, mask the arrival phenology or abandonment of reproduction areas.

Many birds' species with migratory habits have become sedentary after having settled on oceanic islands (Rodrigues *et al*., 2018). In general, when a species reaches an island, it tends to reduce morphological adaptations related to fly and increase the size of the hind limbs (Wright and Steadman, 2012; Seguí, 2001; McMinn *et al*., 2005). Factors such as a reduction in the abundance of predators, and other terrestrial bird species (Wright *et al*., 2016) support the hypothesis of "ecological release" as the factor that shapes the morphological evolution of birds on islands (Lomolino, 2005). Therefore, in the populations of settled down birds in the islands, these morphological modifications do not have to be the result of a selection from the dispersion and colonization of the islands, but probably they could have arisen from selection pressures about the populations when they were already present in these islands (Wright and Steadman, 2012). Knowing the migratory status of the populations of a species is of vital importance, since while in the migrating species the evolution of their populations depends on what happens in the breeding areas and in the winter quarters, as well as in the possible areas of sedimentation and during the migratory journey, in the sedentary species the populations depend exclusively on what happens in the area where they are found (Rushing *et al*., 2016).

The Common quail (*Coturnix coturnix coturnix*) is the only migratory Phasianidae in the Palearctic. It has a very wide breeding area encompassing from the Macaronesian islands to Lake Baikal and from Mauritania to the south of the Nordic countries (Guyomarc'h *et al*., 1998). The wintering area is located in the sub-Saharan area. Two subspecies have been described in the Macaronesian islands, *C. c. confisa* and *C. c. coturnix*. The first one is considered sedentary, while the nominal one is considered migratory (Barone and Lorenzo, 2007). The nominal species is described in the Balearic Islands (Martínez, 2010) and it is considered that a small fraction of the population can be wintering or sedentary (Martínez and Suarez, 2007); the evidences of a sedentary or wintering population are more numerous for the population of Menorca (Martínez and Suarez, 2007).

The quail populations of the westernmost distribution area (Guyomarc'h *et al*., 1998; EC, 2009) show a seasonal evolution of abundance highly conditioned to changes in habitat, which are associated with the seasonality of the crop and the temperature (Sardà-Palomera *et al*., 2012). This means that the moment of their arrival, their stay in the area and their departure are synchronized with the topography of the place and the agronomic activities (Sardà-Palomera *et al*., 2012). Although in recent years an effort has been made to know the ecology and dynamics of the Common quail populations, its knowledge is incomplete, especially with regard to the population of the Mediterranean islands. As it is a game species, the management of its populations requires a thorough knowledge of its biological cycle, since phenology will temporarily condition its reproductive cycle and this will affect the density of its individuals and its age structure.

In this study, the variation in the general abundance of quail males and by age during the breeding season on the island of Majorca, based on census and capture of individuals, is analysed. These results are compared with those collected in two populations of the northeast of the Iberian Peninsula for 13 years (2005-2017): (i) Figuerola del Camp, considered mostly a passage population and (ii) Alp, considered not only a breeding population but also an area of reception of young reproductive individuals (Rodríguez-Teijeiro *et al*., 2010), in order to investigate, through indicators such as migratory and reproductive phenology, the migratory status of the Majorca population.

## Study area

The study was carried out in the municipalities of Sineu, Petra, Sant Joan and Vilafranca de Bonany, within the Pla de Majorca region (111-152 m above sea level), corresponding to the Llanos, marinas and sierras hunting region (Barceló *et al*., 2018) (Fig. 1). It is an area with a warm and temperate climate and with an average annual rainfall of 620 mm (Climate-data.org). It presents a suitable habitat for the Common quail, mostly composed of winter cereals (74%: 34% wheat, 27% barley and 13% oats), legumes (7%), fallow fields (17%), vineyards and rainfed trees (2 %). All this represents 90% of habitat useful for quail. The other two locations studied with which Majorca is compared are found in Catalonia: Figuerola del Camp (41.23º N, 1.17º E, Tarragona) at 474 m above sea level, and Alp (42.23º N, 1.53º E, Girona) at 1100 m above sea level. The first one presents a warm and temperate climate with an average annual precipitation of 622 mm (Climate-data.org); the habitat is composed of winter cereals (90% barley and 10% triticale) that represent 31% of useful habitat for the quail, and the rest is constituted of vineyards and rainfed trees. The second presents an equally warm and temperate climate, with more extreme temperatures and with a higher rainfall regime (929 mm of approximate annual average, Climate-data.org); this habitat is the one that presents a greater variety of crops (cereals, meadows, alfalfa) and represents 50% of useful habitat for the quail (Kosicki *et al*., 2014).

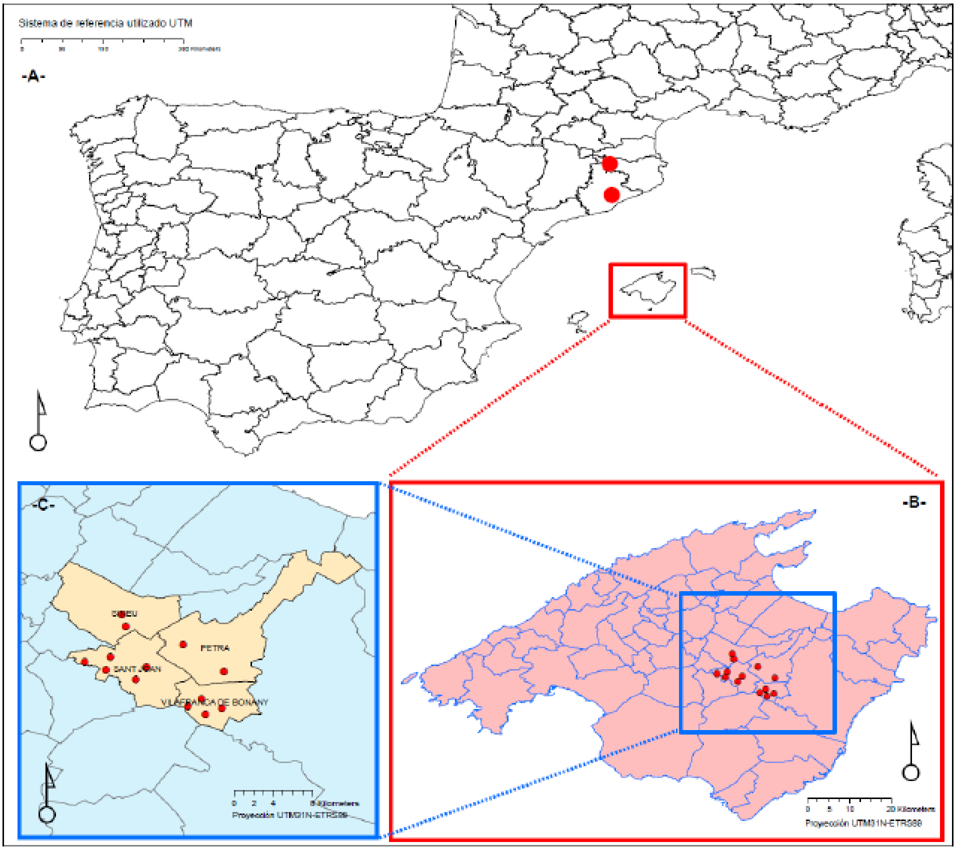


**Fig. 1.** Area of the study carried out in Majorca in which the municipal terms and the 13 listening points are detailed. The localities of the two continental study populations that have allowed the comparison of results are also shown.
***Fig. 1.*** *Àrea de l'estudi realitzat a Mallorca en el qual es detallen els termes municipals i els 13 punts d'escolta. També es mostren les ubicacions de les dues poblacions d'estudi continentals que han permès la comparació de resultats.*

## Material and methods

The study was carried out in Majorca during the breeding seasons of 2017 and 2018. Although data was taken during the 2016 season as well, these data have not been taken into account in the analyses because they correspond to a learning phase of the methodology used and, therefore, not comparable to the other two. The breeding period was defined from the first day in which males were heard singing and responding to the decoy in the study location (by changing their acoustic behaviour or approaching to the decoy) until the day in which 90% of the fields had been harvested (19-VII-2017, 5-VIII-2018), that is, in which the habitat had been destroyed, being thus impossible the reproduction. Since, in the study area of Majorca, and for each season, individuals had already been located before starting field surveys, it must be beard in mind that, in this work, the data of beginning of the breeding season may have been underestimated.

Throughout each season, surveys were conducted with an approximate periodicity of one week (24 per season), starting on March $8^{th}$ in 2017 and February $16^{th}$ in 2018, and ending in both cases on August $9^{th}$. 13 counting points were established (Fig. 1 shows its distribution by municipalities). The census was carried out based on the advertising song of the males (Rodríguez-Teijeiro *et al*., 2010). At each point, an initial listening was performed to locate the males that sang and then a digital female decoy was used to stimulate those males who did not sing spontaneously. Once a male was located within a radius of 350 m, it was tried to capture using the same decoy and placing horizontally a net, whenever possible, on the crop. After capturing it, we proceeded to record the sequence of the primary moult. This sequence indicates the age of the individual. Any individual which had a blocked moult in one of the primaries 5, 6, or 7 (juvenile primary) was considered a yearling. If they did not present this sequence, they were considered adults, following the proposal of Saint-Jalme and Guyomarc'h (1995).

For comparison purposes it was considered the dynamics of the number of males found during the breeding season for the two continental populations from a time series of 13 years (2005-2017, but for Figuerola del Camp year 2008 was not taken into account because it was an anomalous year in terms of the dynamics of the Common quail population, due to the fact that the harvest was not carried out, Rodríguez-Teijeiro *et al*., 2010). The census in these localities was carried out with the same methodology as that explained above, except that in the first days of the survey no males were found singing, so the beginning of the reproductive period in this case could be specified with a variability of ± 7 days. The average date of the end of the harvest (± standard error) in these two places occurred on 23-VI ± 5.9 for Figuerola del Camp and 25-VII ± 2.94 for Alp.

Thus, for each sampling location, three variables were obtained: male census, number of males captured and number of yearlings captured per sampling day. The relationship of these three variables with the Julian day is clearly non-linear, so mixed generalized additive models were used for the analysis (GAMM, Zuur, 2016). Each of these variables was considered the dependent variable while "Julian day" was the covariate. Since the dependent variables are counts, a Poisson distribution of errors was assumed and, as a function link, logarithm. Since censuses were conducted over several years, the "year" was introduced as a random factor in the model. To control the differences between localities in the sampled extension (in Majorca the census consists of 13 sampling points while in Alp and Figuerola del Camp it consisted of 10 points), an *offset* term was introduced in the models with the extension in $km^2$ of the area sampled in each locality. In this way, the estimates of these models are expressed in terms of density (number of individuals counted / $km^2$).

The comparison of the analyses between localities was carried out eliminating one locality each time and, through the AIC, contrasting two models, one incorporating the fixed factor "place" and the other without this incorporation. The model with a smaller AIC in more than two units was chosen. If this was the one with the factor "place", it was interpreted that this factor indicated the existence of differences in the relationship between the dependent variable and the “Julian day” in the two localities considered in the model.

We modelled the capture percentage of yearlings with respect to the total of captures throughout the breeding season using a generalized mixed linear model (GLMM). This model used the "proportion of yearlings" as a dependent variable, "Julian day" as a covariate, "locality" as a fixed factor and "year" as a random factor. A binomial error distribution and a link logit function were assumed. The differences between localities in the "proportion of yearlings" as a function of the "Julian day" were assessed by means of the estimates of the model coefficients.

All the analyses were performed in R 3.5.2 (R Core Team, 2018). The functions (gam) (package mgcv, Wood, 2011) and glmer (package lme4, Bates *et al*., 2015) were used for GAMM and GLMM, respectively. The estimate of GLMM coefficients was done by means of the esticon function (package doBy, Højsgaard & Halekoh, 2018).

## Results

### Dynamics of male census during the breeding season

The males of the Majorca population reported their presence 23 days before the continental population of Figuerola del Camp (Table 1), with which it has similar geographical characteristics; however, unlike the latter, the abundance of males remained more or less constant the first 75 days, after which the density increased steadily over time (Fig. 2).

**Table 1.** Average of cumulative census of males throughout the reproduction season per km$^2$ (± standard error). Julian day in which the first detection of males and yearlings in the locality was carried out. Average Julian day in which the maximum density of males was observed. The values in parentheses indicate the percentiles of 2.5 and 97.5% of the observations of the 13 years.
***Taula 1.*** *Cens mitjà acumulat de mascles al llarg de tota la temporada de reproducció per km$^2$ (± error estàndard). Dia julià mitjà en el qual es va realitzar la primera detecció de mascles i de joves a la localitat. Dia julià mitjà en el qual es va observar la màxima densitat de mascles. Els valors entre parèntesis indiquen els percentils del 2.5 i del 97.5% de les observacions dels 13 anys.*

| | | | Julian day of the first detection | | |
|---|---|---|---|---|---|
| Locality | Period | Census/km$^2$ | Males | Yearlings | Julian day of the maximum census |
| Alp | 2005-2017 | 62.3 ± 6.6 | 114 (105-125) | 141.3 (115.1-165.5) | 171 (145-202) |
| Figuerola del Camp | 2005-2017 | 10.5 ± 1.7 | 79.8 (73-87) | 138.2 (112.4-157.2) | 118 (84.1-131) |
| Majorca | 2017 | 58.8 | 67 | 151 | 200 |
| | 2018 | 54.4 | 47 | 151 | 180 |

The GAMM model incorporating the fixed factor "locality" shows a lower AIC (Table 2), indicating that there are differences between the localities in the dynamics of male density throughout the breeding season. There is a clear relationship between the Julian day and the density of males / km$^2$ throughout the breeding season in the three populations studied (Table 3), showing a strong interannual variation (random factor "year", Table 3) in the continental populations. Both in the Majorca population and in that of Figuerola del Camp the evolution of the census presented a unimodal form, although between both the modal value was displaced in time (Fig. 2). The maximum value of the curve was reached 72 days earlier in the continental population (Table 1); therefore, in Majorca, the reproductive activity started before but the maximum density of males was reached later. The population of Alp reached a first maximum on June 9 (Julian day 159), after which it remained at a more or less constant density until the end of the season (the confidence interval in this range is very broad, Fig. 2). Finally, the maximum density in the population of Majorca was much higher than that detected in Figuerola del Camp, with very similar habitat characteristics, and very similar to that detected in Alp, where a more suitable habi-

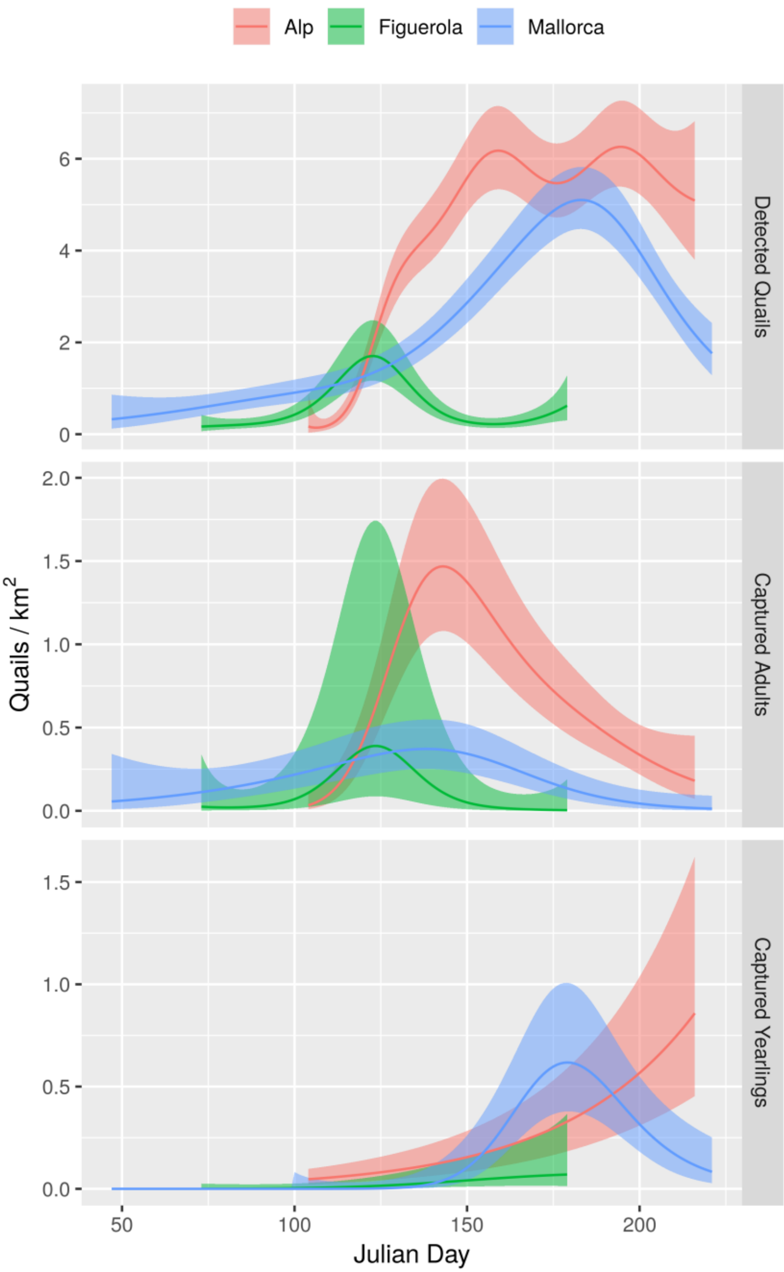


**Fig. 2.** Evolution throughout the breeding season of the density of the populations of quail males detected in the study localities and of the captured males classified as adults or yearlings. The shaded area indicates the confidence interval of the estimate at 95%.

***Fig. 2.*** *Evolució de la densitat de les poblacions de mascles de guàtlera detectats en les localitats d'estudi i dels mascles capturats classificats com a adults o joves. L'àrea ombrejada indica l'interval de confiança de l'estima al 95%.*

**Table 2.** Adjustments of two GAMM models, without fixed factor "place" (model a) or with fixed factor "place" (model b) to the variability in the density of males, density of adults and density of yearlings captured according to the Julian day . Df: degrees of freedom, AIC: Akaike information criterion. % deviance: percentage of variation explained by the model. In bold: the chosen model.
***Taula 2.*** *Ajustaments de dos models GAMM, sense factor fix "lloc" (model a) o amb factor fix "lloc" (model b) a la variabilitat en la densitat de mascles, densitat d'adults i densitat de joves capturats en funció del dia julià. Df: graus de llibertat, AIC: criteri d'informació d'Akaike. % Desviació: percentatge de variació explicada pel model. En negreta el model triat.*

| | Density of males | | | Density of adults | | | Density of yearlings | | |
|---|---|---|---|---|---|---|---|---|---|
| Models | df | AIC | % deviance | df | AIC | % deviance | df | AIC | % deviance |
| a | 26.2 | 2619.4 | 70.6 | 28.5 | 1280.6 | 49.3 | 22.2 | 620.0 | 60.4 |
| b | 41.4 | **2080.9** | 83.1 | 34.3 | **1130.1** | 62.8 | 23.4 | **596.4** | 63.7 |

**Table 3.** Results of the analysis of generalized mixed additive models (GAMM) performed on the density of males / km$^2$ (census), density of adults / km$^2$ (adults) and density of yearlings / km$^2$ (yearlings) captured according to the Julian day (covariate) and of the year (random factor). Figuerola del Camp did not take into account the year 2008 because it was an anomalous year in terms of the population dynamics of the quail because crops were not harvested (Rodríguez-Teijeiro *et al*., 2010). *N*: number of data, *e.d.f.*: effective degrees of freedom.
***Taula 3.*** *Resultats de l'anàlisi dels models additius mixtes generalitzats (GAMM) realitzats sobre la densitat de mascles / km$^2$ (cens), densitat d'adults / km$^2$ (adults) i densitat de joves / km$^2$ (joves) capturats en funció del dia julià (covariable) i de l'any (factor aleatori). En Figuerola del Camp no es va tenir en compte l'any 2008 per ser un any anòmal pel que fa a la dinàmica de la població de la guàtlera a causa que no es va segar (Rodríguez-Teijeiro et al., 2010). N: nombre de dades, e.d.f.: graus de llibertat efectius.*

| | | | Julian day | | | Year | | |
|---|---|---|---|---|---|---|---|---|
| *Locality* | *variable* | *N* | *e.d.f.* | $\chi^2$ | *p* | *e.d.f.* | $\chi^2$ | *p* |
| Alp | Density of males | 372 | 6.9 | 301.9 | 0.0001 | 11.4 | 289.8 | 0.0001 |
| | Density of adults | 372 | 3.9 | 114.3 | 0.0001 | 10.0 | 64.1 | 0.0001 |
| | Density of yearlings | 372 | 1.0 | 70.7 | 0.0001 | 10.7 | 132.7 | 0.0001 |
| Figuerola del Camp | Density of males | 372 | 4.8 | 240.6 | 0.0001 | 10.7 | 110.3 | 0.0001 |
| | Density of adults | 372 | 3.8 | 93.0 | 0.0001 | 10.9 | 27.2 | 0.004 |
| | Density of yearlings | 372 | 1.7 | 9.1 | 0.01 | 4.2 | 12.0 | 0.002 |
| Majorca | Density of males | 372 | 4.6 | 205.1 | 0.0001 | 0.0 | 0.0 | 0.6 |
| | Density of adults | 372 | 2.7 | 16.2 | 0.002 | 0.0 | 0.0 | 0.4 |
| | Density of yearlings | 372 | 2.0 | 7.7 | 0.01 | 0.8 | 4.1 | 0.03 |

tat to quail is presented (Table 1, Fig. 2). The final tail of the curves also shows different characteristics according to the localities; thus, while in Figuerola de Camp the evolution in the male population is closely synchronized with the cereal cycle (the population of males had almost disappeared when 90% of the habitat had been mown), both in Majorca and in Alp the population of males was still very large when the habitat had practically disappeared (Fig. 2).

### Dynamics of the young males and adults fraction during the breeding season

The yearlings were captured for the first time in Majorca on May 31st (Table 1), that is, 84 and 104 days (2017 and 2018, respectively) after the first males had been detected in the locality. However, in Figuerola del Camp the presence of yearlings occurred 58 days after the first detection of individuals in this locality, while in Alp it occurred 27 days after the first detection (Table 1). The proportion of young individuals captured with respect to total catches varied with the Julian day ($\chi^2_1$ = 115.7, p << 0.001, Fig. 3) and this proportion was different according to the localities (locality factor: $\chi^2_2 = 6.0$, $p = 0.05$). The model also shows that the proportion of yearlings according to the Julian day varied between localities (interaction: $\chi^2_1 = 13.4$, $p << 0.002$, Table 4, Fig. 3). The post-hoc test shows that while this relationship does not differ significantly between Figuerola del Camp and Majorca (Table 5), these two locations show clear differences with Alp (Table 5). The proportion of yearlings compared to what was captured during the reproduction period is less pronounced in Alp (Table 5). The proportion of yearlings with regard to the total of captures increases throughout the breeding season in the three localities, but this increase is less pronounced in Alp (Table 4), so in this place adult males are still captured at the end of the breeding season. In the other two locations, in that period, the capture of adults is negligible in Figuerola del Camp or null in Majorca (Fig. 3).

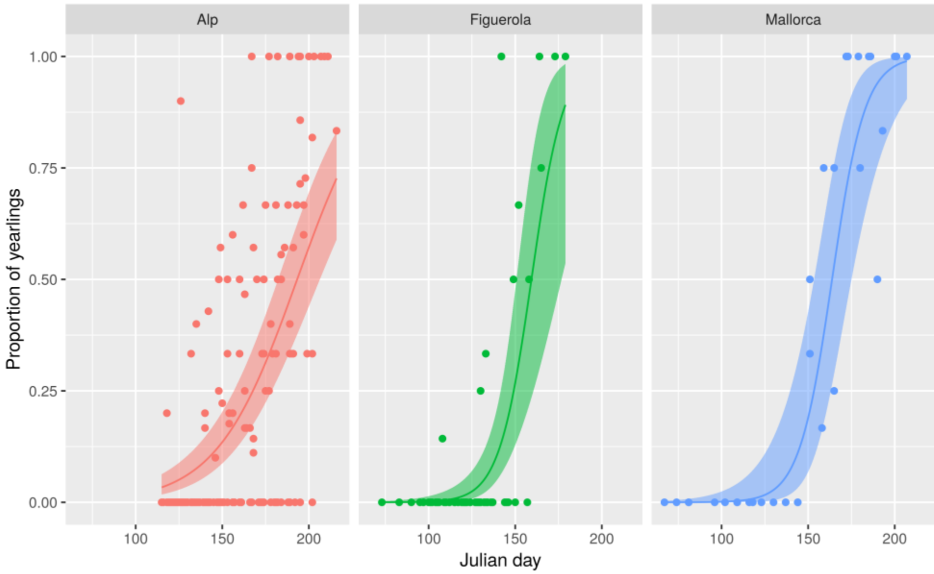


**Fig. 3.** Evolution of the proportion of yearlings captured in relation to the total of individuals captured for the three populations studied throughout the breeding season. The shaded area indicates the confidence interval of the estimate at 95%.

***Fig. 3.*** *Evolució de la proporció de joves capturats en relació al total d'individus capturats per a les tres poblacions estudiades al llarg de l'estació reproductora. L'àrea ombrejada indica l'interval de confiança de l'estima al 95%.*

The density of both young and adult individuals captured / km$^2$ varies depending on the Julian day and the model improves if it is incorporated as a fixed factor "locality" (Table 2), thus indicating that this relationship is different depending on the locality (Fig. 2). The results of the GAMM analysis are shown in Table 3 and, as shown in figure 2, the shape of the curve is very different according to the density of adults or yearlings captured. In adults, the density follows a unimodal distribution similar to that shown in the census, increasing at the beginning of reproduction and once a maximum value has been reached at different times of the reproductive cycle according to the locality, a decrease begins which in the three localities reaches values close to zero (Fig. 2). The comparison between locations indicates that it is different in all of them (Table 6). However, the evolution of yearlings density throughout the breeding period shows a similar exponential trend in the two continental populations (Table 6) and very different from the unimodal form observed in the population of Majorca that resembles that obtained for adults but displaced towards the end of the breeding season. In the latter case, as well as in Alp, the density of yearlings at the end of the harvest is notorious (Fig. 2).

**Table 4.** Results of the generalized linear model of the fraction of yearlings captured from the total captures throughout the breeding season for the three localities. (SE) standard error. * indicates p << 0.0001.
***Taula 4.*** *Resultats del model lineal generalitzat de la fracció de juvenils capturats del total de captures al llarg de la temporada de reproducció per a les tres localitats. (SE) error estàndard. *indica p<<0.0001.*

| | *Intercept* | *SE* | $\chi^2$ | *Slope* | *SE* | $\chi^2$ |
|---|---|---|---|---|---|---|
| Alp | -8.3 | 0.8 | 108.73* | 0.04 | 0.0 | 94.35* |
| Figuerola del Camp | -17.1 | 3.4 | 25.14* | 0.11 | 0.02 | 19.98* |
| Majorca | -17.22 | 3.8 | 20.35* | 0.11 | 0.02 | 20.31* |

**Table 5.** Post-hoc comparisons between localities in the relationship between the fraction of yearlings captured with respect to the total number of captures and the Julian day. In the upper squares the significance of the intercept is shown and in the lower squares the significance of the slope is shown.
***Taula 5.*** *Comparacions post-hoc entre localitats en la relació entre la fracció de juvenils capturada respecte al total de captures i el dia julià. En les caselles superiors es mostra la significació de l'intercept i en les caselles inferiors la significació de la pendent.*

| | Alp | Figuerola del Camp | Majorca |
|---|---|---|---|
| Alp | -- | 0.01 | 0.02 |
| Figuerola del Camp | 0.008 | -- | 0.98 |
| Majorca | 0.009 | 0.95 | -- |

**Table 6.** Comparison between localities from the adjustment of male density, density of adults and density of yearlings according to the Julian day without taking into account the fixed factor "place" (model a) or taking into account this fixed factor (model b). *df*: degrees of freedom, *AIC*: Akaike information criterion, *% deviance*: percentage of variation explained by the model. In bold the chosen model.
***Taula 6.*** *Comparació entre localitats a partir de l'ajust de la densitat de mascles, densitat d'adults i densitat de joves en funció del dia julià sense tenir en compte el factor fix "lloc" (model a) o tenint en compte aquest factor fix (model b) . df: graus de llibertat, AIC: criteri d'informació d'Akaike,% deviance: percentatge de variació explicat pel model. En negreta el model triat.*

| | | Males density | | | Adults density | | | Yearlings density | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Model* | *df* | *AIC* | *% deviance* | *df* | *AIC* | *% deviance* | *df* | *AIC* | *% deviance* |
| Alp *vs* Figuerola del Camp | a | 31.3 | 2309.8 | 71 | 26.8 | 1154.7 | 48.4 | 19.6 | **519.9** | 62.3 |
| | b | 36.1 | **1805.9** | 83.5 | 30.3 | **1012.0** | 62.6 | 19.6 | 525.1 | 61.5 |
| Alp *vs* Majorca | a | 19.2 | 1459.8 | 74.0 | 16.7 | 809.1 | 42.7 | 17.4 | 530.7 | 63.7 |
| | b | 25.0 | **1384.9** | 78.5 | 18.6 | **781.7** | 49.2 | 16.6 | **505.8** | 69.3 |
| Majorca *vs* Figuerola del Camp | a | 20.8 | 1154.4 | 56.9 | 18.0 | 495.7 | 54.6 | 8.7 | 170.5 | 52.2 |
| | b | 21.3 | **970.1** | 70.2 | 19.23 | **469.7** | 59.2 | 10.6 | **161.5** | 56.5 |

## Discussion

The variation of the daily census throughout the season (shape of the curve, Fig. 2), as well as the maximum number of individuals registered, were different in the three populations studied, indicating that there are different population dynamics at a local level. This study shows that the quail starts earlier its breeding activity on the island of Majorca. As a general rule, the beginning of the reproductive activity is related to the latitude, altitude and monthly average temperature (Puigcerver *et al*., 1989; Sardà-Palomera *et al*., 2012); therefore, the earliest start could be associated to the lower latitude of Majorca with respect to the continental populations, as the migratory wave follows a movement from south to north through the Iberian Peninsula (Sardà-Palomera *et al*., 2012). With respect to altitude, Puigcerver *et al*. (1989) found that localities such as Alp, located at higher altitudes, have a later start in reproduction than populations located at lower altitudes (such as Figuerola del Camp) and, in the case of this study, this could also apply to Majorca , since it is located at the lowest altitude of the three populations studied. With regard to temperature, it has been shown that the arrival phenology of the quail in the Iberian Peninsula occurs when it exceeds 7ºC (Sardà-Palomera *et al*., 2012). In the localities studied in Majorca, the lowest average monthly temperature occurs in January and does not fall below 9.8ºC (Climate-data.org). However, the advance in the detection of males in the samplings of the island coincided with the phenology recorded for the southernmost quail populations of the Iberian Peninsula (Seville: Julian day 57, pers. obs.), where it is considered a wintering species (BirdLife International, 2018). Therefore, this early phenology registered in the localities of Majorca together with the geographical and environmental conditions suggests that at least a fraction of the population of Majorca is wintering or sedentary in the locality, as suggested by Martínez and Suarez (2007). In agreement with this, a part of the population of the Gymnesic Islands presents morphological and coloration traits (Rodríguez-Teijeiro *et al*., 2018; Jiménez-Blasco *et al*., 2019) which are compatible with a differentiation towards a lower mobility, such and as predicted by the hypothesis of "ecological release" (Lomolino, 2005), suggesting also the existence of sedentarisation and a certain population isolation.

In both continental populations, the phenology of young males during the reproductive cycle was detected very early (between 27 and 58 days), while on the island this happened between three and three and a half months (85 and 104 days, 2017 and 2018 respectively) after the detection of the beginning of reproduction on the island. If we take into account that from the beginning of the laying of eggs until the data in which yearlings reach sexual maturity there is a time lapse between 75 and 80 days (Saint-Jalmes and Guyomarch ', 1995; Rodríguez-Teijeiro *et al*., 2010), yearlings captured in the continental populations before this temporal margin are the product of a juvenile dispersion of individuals born in other localities of lower latitude and / or altitude (Guyomarch '*et al*., 1998; Perennou 2009). In the Majorca population, young males were captured after this temporary margin, so that they could already belong to the fraction of sexually mature yearlings born in the area itself. Although in Majorca, we cannot discern between yearlings born in the same area and those immigrating from other localities, this delay with respect to the continental populations, suggests a greater geographical isolation of the Majorca population during at least two thirds of its reproductive cycle.

In Majorca and Figuerola del Camp, the global census of males (adults and yearlings) showed a fall at the end of the breeding period associated in time with a decrease in adult captures and an incorporation of yearlings which was not intense enough to mitigate it. However, although in Alp there was also a decrease in adult captures, the incorporation of yearlings was able to counteract it. The causes that produce this decrease in the number of adults are not well established, since the methodology used does not allow to discern between a possible loss of sexual activity in adult males (which would lead them to not respond to the decoy while they still remain in the area), and an early departure from their breeding localities.

In the population of Figuerola del Camp, the evolution of the global census of the males followed a distribution synchronized temporarily with the evolution of the habitat; that is, it coincided with the presence of cereal crops and ended with the harvest time. On the other hand, both in the population of the island and in the continental one of greater altitude (Alp), this synchronization was lost at the end of the season because of the destruction of the habitat caused by the harvest. The sudden loss of habitat interrupted, therefore, the reproduction in a moment in which these populations still had sexually active individuals to continue it (yearlings and adults), being able to act as an ecological hotbed or trap (Kosicki *et al*., 2014 ). This interruption will fundamentally affect the phase of formation of pairs and laying of eggs since the females with chicks that survive the harvest, will continue with the process of raising the chicks, taking advantage of adjacent areas with availability of habitats. The effect that a hotbed or ecological trap may have on the quail population has not been studied in depth.

During the two years of study on the island, the maximum value of the census reached in the quail population was very similar to that found in the population of Alp, considered one of the most densely populated populations within the Atlantic continental distribution area (except for Morocco, Rodríguez-Teijeiro *et al*., 2010). This result is consistent with the fact that island populations tend to have higher population densities than inland populations (MacArthur *et al*., 1972). Among the mechanisms that would favour this increase, low interspecific competition and low risks of predation have been cited (MacArthur *et al*., 1972; Adler and Levins, 1994).

The main conclusion of this study is that the temporal pattern of quail abundance in Majorca is different from that of the continental populations. The early presence of breeding individuals and the temporary delay in the presence of young breeders born within the year suggest on the one hand the possible winter stay of a fraction of the population and on the other one the existence of a certain isolation from it in relation to breeding in the continent. The lack of synchronization between the pattern of abundance of breeding stock and the cereal cycle suggests the need of conducting a more detailed study in order to take into account the possible key effects for proper management and conservation of the species.

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