ENVIRONMENT, WELL-BEING, AND BEHAVIOR

Influence of the breeding system on the escape response of red-legged partridges \((Alectoris rufa)\)


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ABSTRACT This study aimed to determine the influence of the breeding system on the escape response of red-legged partridges comparing 147 free-born partridges captured in the wild \((W)\) and 164 partridges from a commercial hunting farm with an intensive production system \((F)\). All birds were individually released to the natural environment using wooden cages; the escape response was recorded with a high resolution video camera and 4 behavior parameters were analyzed: reaction time or latency, escape type, angle at the moment of flight start, and distance flown. There were significant differences on the mean reaction time depending on the origin of the partridges: 0.43 s, with a maximum of 9 s, for the \(W\) and 52.90 s, with a maximum of 120 s, in 32.3\% of the \(F\) birds. Only one of the \(W\) partridges \((0.68\%)\) escaped by walking, whereas all the other \(W\) birds, and 69.5\% of the \(F\) partridges, flew; the differences in the type of escape reaction between origins were significant. Considering the angle of flight start, the differences were also significant because 98.6\% of \(W\) partridges showed less than 45° angles, whereas 37.7\% of \(F\) birds showed angles of more than 45°. Thus, we can conclude that the breeding system has a great influence on the escape response of the red-legged partridges. The intensive management production systems used on the commercial game farms produced obvious changes in the escape reaction of the red-legged partridges, and this could explain the low ability of these birds to integrate and to survive in the wild due to the high predation pressure they undergo when they are used in repopulation processes.

Key words: \(Alectoris rufa\), intensive production, escape response, flight distance, latency

INTRODUCTION

The conclusion of many studies is that hand-reared species produced under captive conditions are extremely vulnerable to predators after their release into the wild, with little possibility of developing antipredator behavioral patterns during the different growing periods being one of the principal reasons (Shier and Owings, 2006). This is particularly evident in galliform hunting species (Zaccaroni et al., 2007): pheasant \((Phasianus colchicus\); Robertson, 1988; Dowell, 1990), gray partridge \((Perdix perdix\); Dowell, 1992; Pataala and Hissa, 1998), or red-legged partridge \((Alectoris rufa\); Pérez et al., 2004; Alonso et al., 2005). In these 3 species, the parameters for the selection of breeding birds used by the commercial producers have mainly been focused on economic criteria. Thus, on commercial hunting farms, the more docile birds were selected, to facilitate adaptation to laying cages of reduced dimensions, for their higher laying capacity, both in the total number of eggs produced and in the precocity to start the laying cycle (Redondo, 1994). This selection process for tame birds produced a loss in the wild character (Gaudioso et al., 2002), something that should be strongly considered when the animals have to be released into the wild.

Pen-reared farming involves chicks growing without contact with the progenitors. If we consider that some animal behavior patterns are acquired and not inherited (Lorenz, 1965) and are modulated by experience and learning (McLean et al., 1999; Griffin et al., 2001; Caro, 2005), this type of handling limits adequate development of behavioral patterns that have to be learned, such as the identification of species mates, group cohesion, exploratory behavior, dispersion, and escape reaction (Nadal, 1992). On the other hand, these farming practices also produce familiarity with captive conditions that could affect the behavior of the birds.

Antipredator strategies of red-legged partridge include different group vigilance patterns, alarm vocalizations (different, depending on the hazard), and nocturnal antipredator behavior. However, the study
of individual escape behavior as a reaction to an imminent risk has received little attention up to now.

Different authors have studied the importance and influence of group size on the individual antipredatory behavior (Lima, 1994, 1995; Roberts, 1996; Ruxton, 1996; Sirota, 2006) and they accept that group vigilance and escape is not always repeatable and is very much influenced by external factors such as limited visibility of their surrounding (Metcalf, 1984), distance between group mates (Lima and Zollner, 1996; Lazarus, 2003), or distance to refuge places (Pöysä, 1994).

On the other hand, the individual escape response seems to be much more repeatable (Davis, 1975; Bagliacca et al., 1996) and, principally, only the variations dependent on the predator type have been studied (Cresswell et al., 2003). Nevertheless, could the breeding system influence the individual escape response of birds produced under captivity conditions? The answer to this question is of great interest in species such as the red-legged partridge. Doing so is the aim of this study because 5 million partridges from commercial hunting farms are released into the wild each year in Spain so as to repopulate and increase the wild partridge population.

**MATERIALS AND METHODS**

**Birds**

One hundred sixty-four hand-reared partridges from a commercial hunting farm with an intensive production system (F), 56 chicks of 2 to 3 mo old in summer and 108 adults of more than 10 mo old in spring (54 males and 54 females), and 147 free-born partridges captured in the wild (W), 76 chicks of 2 to 3 mo old in summer and 71 adults of more than 10 mo old in spring (65 males and 6 females) were used for the present study. The F partridges were produced following intensive handling procedures: newly hatched chicks were placed in brooding rooms within protective rings with a heat source during the first 8 to 10 d posthatch (density of 100 chicks per m²). After 10 d, chicks had access to the whole room heated day and night at 28 to 30°C, until they reached 25 d of age. From 25 to 60 d of age, the birds were given heat during the night and part of the day and allowed access to a small grass area with an animal density of 40 to 50 chicks/m². At 60 d of age, they were placed in large flying pens in which they could fly and stay there until the beginning of the experiment. The study area was described by Pérez et al. (2004). Wild partridges were trapped by cages and were released the day after they were captured; due to capture method, the number of adult W females used in this study was considerably smaller than the adult W males. Farm partridges were cooped at the origin farm the day before they were released. All birds were identified using a metallic numbered ring placed on the right leg of each bird; this prevented the possibility of recapture of birds that were previously released. In this way, all of the birds used in this study had no previous experience with the release process.

**Release Methodology**

All birds were directly released, one at a time, between 1100 to 1200 h using a cage (40 cm length × 30 cm width × 30 cm height) with a wooden base covered with a wire mesh in a triangular form that allowed birds to see the natural surrounding environment in which they were going to be released. A semiautomatic device opened the structure, leaving the space occupied by the bird free and allowing the birds free access to escape. The person in charge of opening the cage was hiding 5 m to the rear of the cage.

A lapse of 5 min passed between the moment the bird was placed in the release cage and the release. This allowed the bird to calm down and standardized the release methodology.

A high-resolution digital video camera of 50 frames/s (Panasonic NV-DS27, Secaucus, NJ) was placed perpendicular to the open direction of the release cages, recording the escape reaction of all partridges.

Time reaction or latency was evaluated using a chronometer, considering the lapse of time between the moment the release cage was opened and the moment in which the partridge started the escape. If the bird stayed in the cage for 120 s after the cage was opened, the person in charge of opening it walked to the cage to frighten the bird, forcing it to escape. Thus, 120 s was the maximum time reaction considered.

The type of escape reaction (walking or flying) and the distance flown evaluated with a laser digital tachometer (Bushnell, Overland Park, KS) was recorded. When birds escaped by flying, the flight start angle was measured using a personal computer, classifying it, by 1 observer, in one of the following values to clarify

<table>
<thead>
<tr>
<th>Item</th>
<th>n</th>
<th>Wild</th>
<th>Farm</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency</td>
<td>147</td>
<td>0.44 ± 0.11</td>
<td>164</td>
<td>52.90 ± 4.06</td>
</tr>
<tr>
<td>Start flight angle</td>
<td>146</td>
<td>26.59 ± 0.88</td>
<td>114</td>
<td>46.55 ± 1.69</td>
</tr>
<tr>
<td>Distance</td>
<td>146</td>
<td>323.16 ± 5.94</td>
<td>114</td>
<td>298.72 ± 7.20</td>
</tr>
<tr>
<td>Type of escape reaction</td>
<td>147</td>
<td>146</td>
<td>1</td>
<td>164</td>
</tr>
</tbody>
</table>
the study: 11.25, 22.50, 33.75, 45, 56.25, 67.50, 78.75, or 90°.

The releases were carried out over 6 consecutive years. The F chicks were released for 12 d over 2 consecutive years and the W chicks on 18 d over 3 consecutive years. The F adults were released for 12 d over 2 consecutive years and W adults for 12 d over 3 consecutive years. Releases were randomized by origins and by sex when possible. We aimed to minimize the prey concentration, to avoid attracting predators, as well as year and meteorological effect on bird behavior. However, with releases across different years, the variability of the study variables was likely increased.

Data Analyses

Differences due to origin and age in the quantitative variables were analyzed with ANOVA fitting a model with origin and age, and their interaction, as

\[ Y_{ijk} = \mu + A_i + B_j + AB_{ij} + \epsilon_{ijk}, \]

where \( Y_{ijk} \) = observation on the \( k \)th bird from origin \( i \) and age \( j \); \( \mu \) = general mean value; \( A_i \) = effect due to origin (farm or wild); \( B_j \) = effect due to age (adult or young); \( AB_{ij} \) = interaction between both factors; and \( \epsilon_{ijk} \) = error.

Chi-squared tests were used to assess the differences of the qualitative variable (Dixon, 1983) also using the computer program SPSS (version 10.0) for Windows (SPSS Inc., Chicago, IL).

We first performed a 1-way ANOVA between years, release point, and sexes when possible and we did not find significant differences in any of the partridge subgroups relative to the age and origin. This allowed us to consider the data independently of these factors after this moment, using the ANOVA factorial or the \( \chi^2 \) test to study the influence of the origin and age and the interaction of both on the escape response.

RESULTS

If we consider the results based on the origin and independently of age, there were significant differences in all studied parameters: reaction time, flight start angle, escape reaction type, and distance flown, as can be seen in Table 1.

When we compared the flight response relative to the age of the birds (Table 2), there were significant differences in the reaction time and distance flown but not in the start flight angle and type of escape reaction.

Taking all W partridge data into consideration, the mean reaction time value was significantly shorter than F birds (Table 1), with no significant differences based on partridge age; even when W adult partridges were more reactive than chicks, mean values were less than 1 s (Table 3) and maximum times were 3 and 9 s, respectively. In the F partridges, there were significant differences relative to the age of the birds but with partridge chicks being more reactive (Table 3).

By grouping W birds by the latency time recorded, we can see that 82.3% (121 partridges) started the escape immediately after the cage was opened (Figure 1). Only 1 chick started the escape by walking (1.3% of the chicks and 0.68% of the total), whereas all other W partridges chose flying as their escape reaction. Using

### Table 2. Mean values (±SE) of latency, start flight angle, distance flow, and total of escape reaction type depending on the red-legged partridge age

<table>
<thead>
<tr>
<th>Item</th>
<th>n</th>
<th>Adult</th>
<th>n</th>
<th>Young</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency</td>
<td>179</td>
<td>36.16 ± 3.78</td>
<td>132</td>
<td>17.17 ± 3.15</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Start flight angle</td>
<td>147</td>
<td>35.87 ± 1.53</td>
<td>113</td>
<td>34.65 ± 1.50</td>
<td>=0.365</td>
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<tr>
<td>Distance</td>
<td>147</td>
<td>322.97 ± 6.01</td>
<td>113</td>
<td>292.07 ± 7.32</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of escape reaction</th>
<th>n</th>
<th>Adult</th>
<th>n</th>
<th>Young</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly  Walk</td>
<td>179</td>
<td>147</td>
<td>32</td>
<td>132</td>
<td>19</td>
</tr>
</tbody>
</table>

### Table 3. Mean values (±SE) of latency, start flight angle, distance flow, and total of escape reaction type depending on the red-legged partridge origin and age

<table>
<thead>
<tr>
<th>Item</th>
<th>n</th>
<th>Adult</th>
<th>n</th>
<th>Young</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latency</td>
<td>71</td>
<td>0.18 ± 0.06</td>
<td>76</td>
<td>0.67 ± 0.20</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Start flight angle</td>
<td>71</td>
<td>23.45 ± 1.05</td>
<td>75</td>
<td>29.55 ± 1.31</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Distance</td>
<td>71</td>
<td>336.58 ± 7.03</td>
<td>75</td>
<td>300.19 ± 9.39</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of escape reaction</th>
<th>n</th>
<th>Wild</th>
<th>n</th>
<th>Farm</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly  Walk</td>
<td>71</td>
<td>71</td>
<td>0</td>
<td>76</td>
<td>55</td>
</tr>
<tr>
<td>Fly  Walk</td>
<td>76</td>
<td>269.71 ± 10.56</td>
<td>38</td>
<td>269.71 ± 10.56</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

**Different letters within the same line indicate significant differences.

*P_w = P-value for wild partridges; P_f = P-value for farm partridges.
the $\chi^2$ test, the differences between chicks and adults were not significant (Table 3).

In F partridges, a high percentage of birds stayed in the cage for 120 s after the cage was opened, 32.3% in total (Figure 2), 19.6% chicks and 38.9% adults, and it was necessary to frighten the birds to force the escape from the cage. Seventy percent of the F partridges escaped by flying and 30% escaped by walking. The $\chi^2$ test revealed no significance in the differences between chicks and adults (Table 3).

The majority of W partridges (98.6%) started their flight with angles less than 45°. The most frequent angles registered were 22.50 and 33.75° (Figure 3). There were significant differences depending on the age because adult W partridges showed smaller flight angles than young W birds (Table 3), and both W birds showed angles significantly lower than F partridges (Table 3). All but one (1.41%) of the adult angles were under 33.75° (Figure 4), whereas 21.34% of chicks showed angles over 33.75° (Figure 4).
Forty-seven percent of F partridges showed flight angles between 33.75 and 45° and 85% of them between 33.75 and 67.5° (Figure 3). Moreover, we have to highlight that 3 birds started the flight perpendicular to the ground at an angle of 90°. There were no significant differences for age (Table 3).

The difference in mean distances flown for the W and F partridges was significant (Table 1) as well as
the differences within adult and young independently of the origin (Table 2), but when we studied the interaction between both factors, we observed that only young F partridges flew significantly less than the other 3 groups (Table 3).

**DISCUSSION**

Based on our results, we can state that the usual escape reaction of W red-legged partridges was an immediate escape to their natural environment as soon as the physical barrier that confined them was removed.

This result agrees with Álvarez et al. (1984), who found, in wild coveys, that escape was immediate after hazard identification, independent of any other factor such as place, climate aspects, or sex. The mean latency value of W partridges was less than 1 s, but the value for young birds was 3 times that of adult birds. Adult birds could have been more sensitive to stressful situations due to the capture handling and release method, perceiving humans as a great threat, and, the moment they realized that they were free to escape, they did so. On the other hand, partridge chicks, with less experience and greater fear of novel situations, took more time before they placed themselves adequately and oriented themselves to minimize their risk during escape.

The increase in the reaction time of young partridges could make them more susceptible to predators. Even with a small time difference, it could be enough to represent the difference between success and failure to face predator attacks. According to Cresswell (1993) in red-shanks (Tringa tetanus) and Lind et al. (2002) in blue tits (Parus caeruleus), small time differences in the escape response can result in capture.

The latency or mean escape time in the F partridges, under the same management conditions, rose to 53 s. This difference in escape behavior is, undoubtedly, due to the taming process and habituation that occurs with intensive farming methods. This is substantiated by the results of Blount and Matheson (2005) with zebra finches (Taeniopygia guttata), in which such latency in reaction time due to captive rearing made them much more vulnerable to predator attack.

Under natural conditions, most predators could not capture wild partridges because the birds would quickly take flight, but the longer time to flight of farm-reared birds makes them easy prey. This logic agrees with the results of Kullberg et al. (1998) and Kullberg and Lafrenz (2007), who reported that the initial escape or take-off response influenced the survival of great tits (Parus major).

Our results also agree with Csermely et al. (1983), who stated that partridge chicks reared under captive conditions with visual contact with humans within the first 48 h of life had shorter flight distances than birds reared without visual contact with humans.

Curiously enough, F young birds had a shorter reaction time than adults. Chicks spent less time in the commercial flying pens and this could have had a positive effect on escape behavior and other alarm or alert patterns because the taming process due to human presence and their familiarity with enclosed areas had less of a chance to adversely affect them. The fact that more than one-third of F birds needed to be frightened to escape after 2 min from the moment the release cage was opened is also noteworthy.

Once they escaped, we observed that in the W group, all birds except one young partridge always flew because this is the quickest and most efficient way to escape from imminent risk. We can conclude that flight is the evasive pattern chosen by partridges under extreme hazardous situations, or when they could not use any other antipredatory strategies such as vigilance, crouching down, or hiding, as described by Pintos et al. (1985), Dowell (1990), and Zilletti et al. (1993). On the other hand, this is the best way to escape from the risk of predators approaching from the ground, such as human, on this occasion, or terrestrial carnivores, such as foxes or dogs.

In the F partridges, 1 out of 3 escaped by walking, independent of age, which increased their susceptibility to terrestrial predator attack and could explain their vulnerability to the predation by foxes and dogs as observed by Pérez et al. (2004) and Alonso et al. (2005). These birds had no contact with adults during the first weeks of life and lacked the opportunity to learn from experienced parents the appropriate antipredator behaviors (Dowell, 1990), which has been identified as one of the most important causes of the high rate of predation recorded after release (Zaccaroni et al., 2007).

Considering flight start method, we can say that partridges that used lower angles to start had a greater opportunity to defend themselves from raptors. Flying near the ground and vegetation makes it difficult for airborne predators to move close to the partridge and allows for fewer options if they fail in the first attack. Thus, adult W partridges used lower angles to start the escape flight, which could be from both the experience gained by surviving previous raptor attacks and the fact that young partridges that used lower angles had a greater chance of surviving to adult age. Bagliacca et al. (1996) pointed out that for pheasant (Phasianus colchicus), the angle to initiate flight is one of the more repeatable antipredator patterns. On the other hand, Kullberg et al. (1998) and Kullberg and Lafrenz (2007) found, in great tits (Parus major), that heavier birds choose to take off with a lower angle to be able to maintain a high speed. Our results agree with this because adult wild partridges that are heavier than young had the lowest escape angles, which allowed them to achieve the highest acceleration (Witter and Cuthill, 1993), increasing their chances of survival. All of this made the adult W birds a selected group of partridges.

Large flight angles, more vertical at the start, with less accelerations result in greater raptor attack success. This is the predominant response in the F partridge group, which could make them more susceptible
to aerial predators than W birds. There were no significant differences in the initial flight angles between adult and young F partridges, independent of the time they spent in the flying pens.

Finally, we found that the mean distance the partridges flew depended on the age of the bird in F birds. This could be due to the fact that the flying ability of adult birds, with completely developed body muscles, enabled them to fly a greater distance once they escaped. The absence of statistically significant differences between the mean distances of adult F and W partridges allows us to state that the captive breeding systems produce birds that learn to fly during their stay in the flight pens before they are used in the repopulation process.

The captive rearing process carried out on the commercial hunting farms results in definite changes in escape behavior of red-legged partridges. Griffin et al. (2000) reported that animals that have been isolated from predators may no longer express appropriate antipredator behaviors. On the other hand, farmed partridges are reared without contact with their parents and they lack the opportunity to learn the appropriate antipredator behaviors from them, as reported by Dowell (1990) and Beani and Dessì-Fulgheri (1998) in gray partridges (Perdix perdix) and Zilletti et al. (1993) in red-legged partridges. All of this explains the decreased ability of farm-reared partridges to integrate into the wild when they are used for repopulation and the high incidence of predation they undergo when released into natural environments, as reported in previous studies by Pérez et al. (2004) and Alonso et al. (2005).

This is not exaggerated predator pressure but the inability of farmed partridges to develop antipredator patterns of defense and escape, which allows opportunistic predators to take advantage of unwary prey. Our results are in agreement with Krause and Godin (1995) and Metcalfe and Ure (1995), who stated, in other prey species, that the speed and agility with which they take off for flight are crucial in determining whether or not a bird will survive a predator attack, and the sooner the prey initiated its flight, the greater the probability of making a successful escape. Thus, our results agree with Bagliacca et al. (1996) that the evaluation of escape parameters could help to determine the ability of farmed game birds to survive, and the more similar the escape behavior of farmed birds is to the wild partridges, the better.

Thus, we can conclude that the breeding system can have a great influence on the escape response of the red-legged partridge. Intensive management production systems used on commercial game farms produce significant changes in the escape reaction of red-legged partridges, which may explain the inability of these birds to integrate and survive in the wild given the high predation pressure they are exposed to when they are used in the repopulation processes. The escape patterns most affected by the artificial rearing process are reaction time or latency, escape type, and angle to start the flight. However, distance flown was not affected, and farm partridges are perfectly able to fly, and this parameter is not useful to evaluate the ecoethological quality of released animals.

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REFERENCES


