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Impact of raptor predation on racing pigeon losses: Insights from Bulgaria and implications for mitigation strategies

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Abstract Racing pigeons confront predation pressure from birds of prey, resulting in human-wildlife conflict and potential illegal persecution of raptors. Despite perceptions among pigeon fanciers, empirical evidence substantiating raptors as the primary threat remains scant. This study aimed to quantify raptor predation on racing pigeons in Bulgaria, identify high-risk areas, and assess mitigation measures. Data were collected through questionnaires and GPS-tracking of pigeon flights during races. Preventive methods such as bright-colored wing patches and painted eyespots were tested. Results revealed raptor attacks as a major cause of pigeon loss, particularly prevalent during spring and in upland woodlands. Pigeons marked with repellents had higher survival rates than unmarked ones, suggesting partial effectiveness of the prevention methods. Phenology data on raptor attacks and appropriate preventive measures, established in close collaboration with pigeon fanciers, can facilitate mitigating human-raptor conflict. Further research and conservation initiatives are advocated to address this persistent issue. This study underlines the importance of incorporating stakeholder perspectives and deploying targeted conservation strategies to alleviate human-wildlife conflicts involving raptors and racing pigeons.

Keywords: human-wildlife conflict, domestic pigeons, birds of prey, anti-raptor repellent, GPS-tracking

Összefoglalás A versenypostagalambok jelentős predációs nyomásnak vannak kitéve ragadozó madarak részéről, ami ember-állat konfliktushoz és a ragadozók potenciális illegális üldözéséhez vezet. Annak ellenére, hogy a galambkedvelők megítélése szerint a ragadozók jelentik az elsődleges fenyegetést, az ezt alátámasztó tudományos bizonyítékok hiányoznak. Ez a tanulmány arra irányult, hogy meghatározza a ragadozók által okozott veszteségeket a versenypostagalambok között Bulgáriában, azonosítsa a magas kockázatú területeket, és tesztelje a csökkentő intézkedéseket. Az adatokat kérdőívek és a galambok repüléseinek GPS-nyomkövetése révén gyűjtötték össze versenyek alatt. Megelőző módszereket, például élénk színű szárnyakat és festett szemfoltokat teszteltek. Az eredmények azt mutatták, hogy a ragadozók támadásai a legfontosabb okai a galambveszteségnek, különösen tavasszal és hegységi erdős területeken. A taszító jelzésekkel ellátott galamboknak magasabb túlélési arányuk volt, mint azoknak, amelyek nem voltak megjelölve, ez a megelőző módszerek részleges hatékonyságát sugallja. A ragadozók támadásainak fenológiája és az alkalmazott megelőző intézkedések, amelyeket a galambkedvelőkkel szorosan együttműködve állapítottak meg, segíthetnek az ember-ragadozó konfliktus enyhítésében. További kutatásokra és védelmi kezdeményezésekre van szükség e probléma kezeléséhez. Ez a tanulmány hangsúlyozza a résztvevői nézőpontok figyelembevételének fontosságát és a célzott konzervációs stratégiák végrehajtását a ragadozókat és a verseny postagalambokat érintő ember-állat konfliktusok enyhítésére.

Kulcsszavak: ember-állat konfliktus, házi galambok, ragadozó madarak, ragadozó taszító, GPS-nyomkövetés

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Introduction

Birds of prey frequently contribute to human-wildlife conflicts due to predation on economically valuable species, such as domesticated racing pigeons (Henderson *et al.* 2004, Kettel *et al.* 2021). Racing pigeons are utilized for endurance flights lasting from several to 22 hours (tipplers and highflyers), as well as for speed races covering distances ranging from 100 to over 1,000 kilometers (homing pigeons). The global practice of racing pigeons, organized with scoring systems and prizes, is deeply entrenched within a community of enthusiasts who consider it a sport rather than merely a hobby (RPRA 2023). Apart from the emotional bond between fanciers and their birds, high-quality racing pigeons can yield substantial economic returns, sometimes exceeding hundreds of thousands of euros per individual (The New York Times 2020).

While the number of pigeon fanciers may be declining in Europe, interest in the sport is burgeoning in Asia, with significant participation observed in Beijing and Taiwan (Business Insider 2019). Nevertheless, Europe remains a pivotal hub for pigeon racing, particularly in the UK, Belgium, and the Netherlands, boasting tens of thousands of enthusiasts (Kettel *et al.* 2021, France24 2022, The Guardian 2022).

Despite its popularity, the racing pigeon community faces challenges, notably substantial mortality rates during racing seasons, with only approximately 20% of pigeons surviving one-loft races (BENZING 2023). While various factors contribute to pigeon losses, fanciers commonly perceive birds of prey as the primary threat (Armstrong 1991, Henderson *et al.* 2004, Kettel *et al.* 2021), although this perception often lacks scientific evidence (Kettel *et al.* 2021). Additionally, conflicts between pigeon fanciers and raptors can escalate into illegal persecution, including trapping, shooting, poisoning, or nest destruction (RSPB 2014, BSPB unpubl. data). Thus, quantifying raptor predation on racing pigeons and identifying effective prevention measures are vital from a conservation standpoint (Henderson *et al.* 2004, Kettel *et al.* 2021).

In Bulgaria, pigeon sport is quite popular, and pigeon fanciers are organized into local clubs and national-level associations (BFFHEF 2023, BRPA 2023, BRPF 2023). However, there is a lack of quantitative research or published evidence regarding raptor predation on racing pigeons, as well as on the efficiency of any measures to mitigate human-raptor conflict in the country.

This study aims to assess the magnitude of racing pigeon losses due to birds of prey in Bulgaria and test the effectiveness of some mitigation measures.

Materials and Methods

Data collection through questionnaires

Perceptions of pigeon fanciers were surveyed through a structured questionnaire comprising 28 inquiries. These encompassed aspects such as lofts locations, number of pigeons owned, pigeon care practices, timing of trainings and races, ranking of threats

(rated on a scale from 1 – very low to 5 – very high), magnitude of pigeon losses, methods applied to mitigate losses, phenology of raptor attacks (timing of the day and season) and the identification of the major groups of raptors most frequently attacking pigeons. The questionnaire was disseminated online via pigeon fancier media platforms and distributed as hard copies during seminars conducted with pigeon clubs. In 2022–2023, a total of 201 completed questionnaires were obtained from pigeon fanciers in 65 municipalities across Bulgaria, which represents 25% of the municipalities in the country (n = 265 municipalities).

Data collection by use of GPS rings during pigeon races

To collect data about location, habitat and frequency of raptors' attacks on homing pigeons, we used SKYLEADER GPS pigeon identification tracker rings (Satellite System – GPS + GLONASS Dual-core System). The GPS rings (n = 18) collected information about geographic position, direction, speed and height of flight. The GPS logging modes were selected based on the flight distance and duration, as follows: (i) GPS location in every two s for flight durations up to two hours (distance 100–150 km); (ii) GPS location in every 35 s

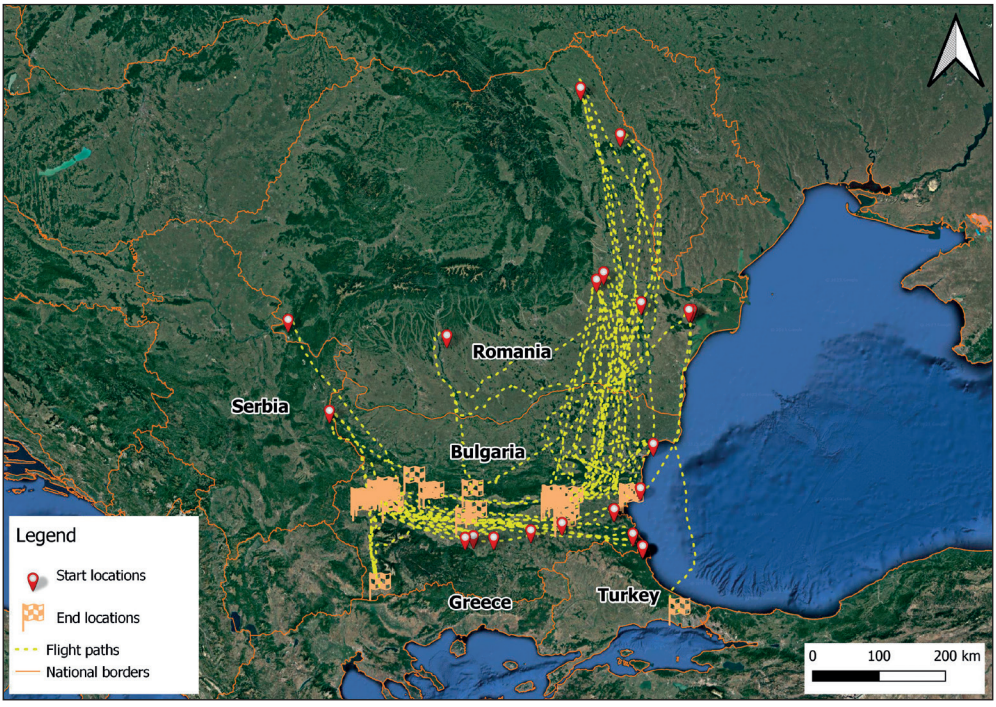

Figure 1. Map with the tracks of GPS marked racing pigeons in 2022–2023 (n = 72 individual pigeon flights tracked during 23 races). Start points were located in ten areas in Bulgaria and six areas in Romania

1. ábra A 2022–2023-ban GPS-jeladóval megjelölt versenygalambok útvonalainak (n = 72 egyedi repülés, 23 verseny során nyomon követve) térképe. Tíz elengedési pont Bulgáriában, hat Romániában volt

– for flights up to six hours (distance up to 400 km); (iii) GPS location in every 180 s – for one day long-distance flights up to 12 hours (600 km); and (iv) GPS location in every 375 s – for over-night long-distance flights up to 35 hours (> 600 km). The weight of GPS rings was 4 g and the devices were attached to the pigeon's legs. To adapt pigeons to the GPS rings and minimize any potential negative impact on their flight ability, the pigeons were marked with dummy rings, with the same weight, dimensions, and shape as the GPS rings, at least two weeks prior to the races. The GPS rings were powered by rechargeable Lithium-ion polymer battery with endurance up to 35 h. Downloading telemetry data was only possible by wired base station upon the return of the pigeon to the loft.

In total, 72 individual pigeon flights were tracked during 23 races where in total 11,740 pigeons took part. In few cases, the same pigeons carried the GPS rings more than once, but the release points, distance, duration and itinerary of the flights were different. All pigeons were raced by fanciers located in South Bulgaria and the racing start points were at 16 locations: ten in Bulgaria and six in Romania *(Figure 1)*.

Test for efficient deterrent methods to mitigate raptor predation on racing pigeons

In 2022, we checked all online platforms in Bulgaria for products advertised to reduce raptors attacks on pigeons and there was just one single product available on the market – the anti-raptor spray. To test for the efficiency of this deterrent method, anti-raptor sprays were distributed to 50 volunteering pigeon fanciers. The method consisted of spraying a bright-colored patch (ca. five cm in diameter) on the upper side of the pigeon's wing *(Figure 2)*. The patch color, unknown in the wild, was supposed to have a deterrent and irritating effect on birds of prey and thus prevent losses (Götmark 1994). The fanciers participating in

Figure 2. Painted eyespots on racing pigeons (homer on the left, highflyer on the right), under the current experiment to test for the efficiency of deterrent effect on raptors

2. ábra Festett szemek a versenygalambokon (balra postagalamb, jobbra magasröptű galamb), a ragadozómadarak elriasztásának hatékonyságát vizsgáló kísérlet során

the experiment were instructed to spray only a ratio of their pigeons in the flocks, so that unmarked birds can be used as controls.

We also tested for the efficiency of eyespots method, as a combination between the bright-color wing patch (Götmark 1994) and Codice LIVIA (Federazione Colombofilia Italiana 2014) methods. We painted contrast eyespots on both upper wings of pigeons. As background colors, we used both yellow and pink, but we did not account for the effect of background color due to the small sample size. Eyespots were painted in 72 homers and highflyers (14%) out of 499 raced pigeons in total, belonging to seven fanciers (these birds were independent from the GPS marked individuals). At the end of the racing season, we compared the survival rate of eyespot painted pigeons with non-painted pigeons in the same flocks to assess the raptors deterrent impact.

Data interpretation and analysis

The relative weight of the factors causing pigeon losses was calculated as a ratio of the scoring for a single factor divided to the total sum of scoring points (n = 763) and results were presented as a percentage (Stara *et al.* 2022).

The information collected by the GPS rings was downloaded and displayed via SKYLEADER V2.0 software. A raptor attack was considered probable when rapid shift in the direction, speed and height of flight occurred, often resulting in abrupt landing of the pigeon in unusual habitat (e.g. woodland) for considerable time period – e.g. over an hour (Santos *et al.* 2015). Landing of pigeons in settlements or near water bodies along the tracks were excluded from the analysis. Our analysis is based only on unsuccessful raptor attacks on pigeons, as the data collected from the GPS rings were only from pigeons that successfully returned to their lofts.

The efficiency of bright-colored wing patches method was evaluated based on comparison between survival rates in spray-marked vs unmarked pigeons. The data collected and suitable for analysis came from 66% (n = 33) of the fanciers participating in the survey, who have sprayed a total of 1,080 pigeons (44%), out of 2,473 pigeons they own, both homing pigeons and highflyers.

Results

General features of surveyed pigeon fanciers in Bulgaria (2022–2023)

Of all respondents (n = 201), 87% race their pigeons, whereas 13% keep pigeons purely for their aesthetic appeal, or for external selection and competitions. The interviewed fanciers had on average 125 pigeons per person (ranging from 2 to 1,000 birds) and raced on average 66 pigeons (ranging from 4 to 500 birds). In total, 93% of the fanciers (n = 187) were regularly vaccinating their pigeons and applying other preventive medicine. Most of the fanciers (48%, n = 96) were participating in 1–10 races per year, 30% (n = 60) – in 11–15 races, 11% (n = 22) in 16–20 races, 5% (n = 10) – in over 20 races per year, and 6% (n = 11) do not participate in races at all.

Preventive measures applied

More than half of the pigeon fanciers interviewed (60%, n = 120) do not apply any measures to prevent raptor attacks. In those who apply measures (39%, n = 79), the mitigation methods were not exclusive (i.e. some fanciers were applying multiple methods simultaneously), 1% (n = 2) of the respondents did not answer this question. The most common method to reduce raptor attacks was a strict regime of pigeon release and training according to the time of the day and the season (31%), while in some cases pigeons were kept closed during the winter (10%). Another common method was the bright-colored wing patches made with anti-raptor sprays (21%). Few pigeon fanciers were applying alternative methods, such as making noise (6%), keeping pigeons closed all year round (6%), installing owl decoys on the roof (3%) and breed more individuals to compensate for the losses (3%).

There was no difference in the general pigeon loss rate between the fanciers applying preventive measures (n = 75) and those who do not apply any measures (n = 115) *(Figure 3)*. However, when considering only the pigeon loss rate caused by raptors, it was 14% lower in the fanciers applying measures but it should be noted that these data is based on the perceptions of the fanciers *(Figure 3)*.

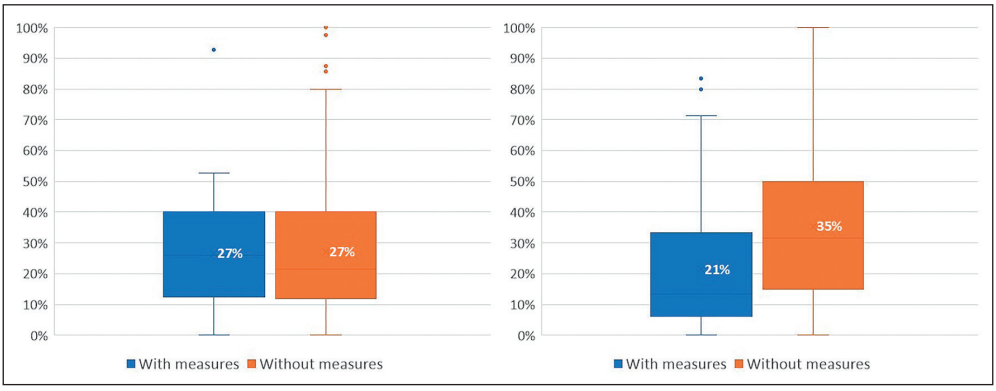

Figure 3. Comparison of general pigeon loss rate (left) and loss rate caused by raptors (right) between the fanciers applying preventive measures and those who do not apply any measures (n = 201 interviewed fanciers)

3. ábra Az összes galambveszteség arányának (balra) és a ragadozók által okozott veszteség arányának (jobbra) összehasonlítása azok között a galambtartók között, akik alkalmaznak megelőző intézkedéseket, és azok között, akik nem alkalmaznak (n = 201 megkérdezett galambtartó)

Factorial weight, phenology and frequency of raptor attacks

Based on the results collected from the questionnaire, raptor attacks were rated as the most significant cause of pigeon loss (25%), followed by bad weather conditions, disorientation, diseases and collisions with power lines (10–16%) *(Figure 4)*. Predation by terrestrial carnivores, theft or shooting were also listed as factors but with very low impact (6–10%). Negligible impact was accounted to unintentional poisoning and collision with other objects

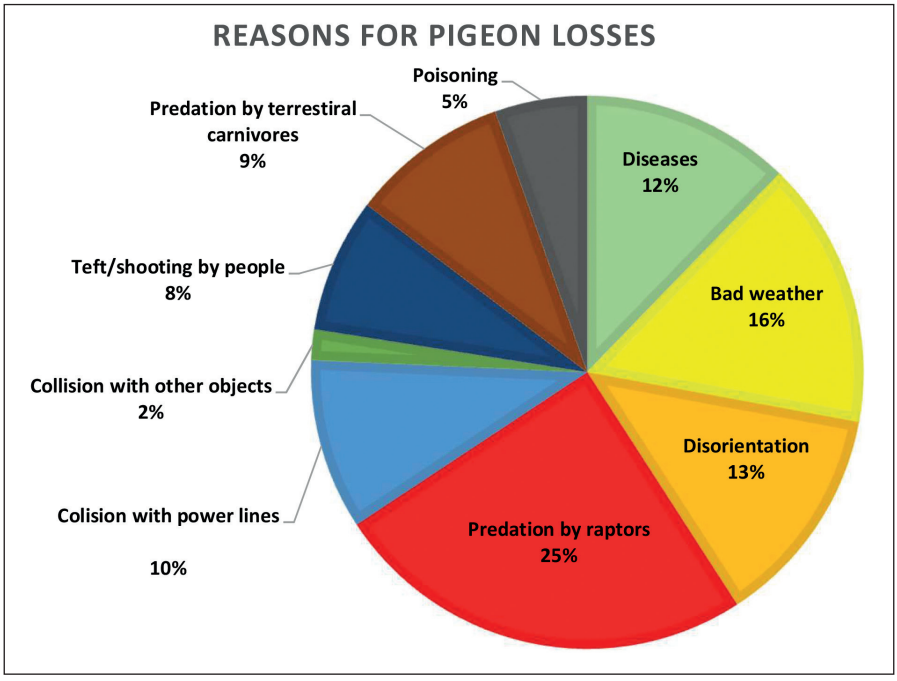

Figure 4. Ranking of the factors causing racing pigeon losses in Bulgaria (n = 201 interviewed fanciers)

4. ábra A versenygalamb-veszteséget okozó tényezők rangsora Bulgáriában (n = 201 megkérdezett galambtartó)

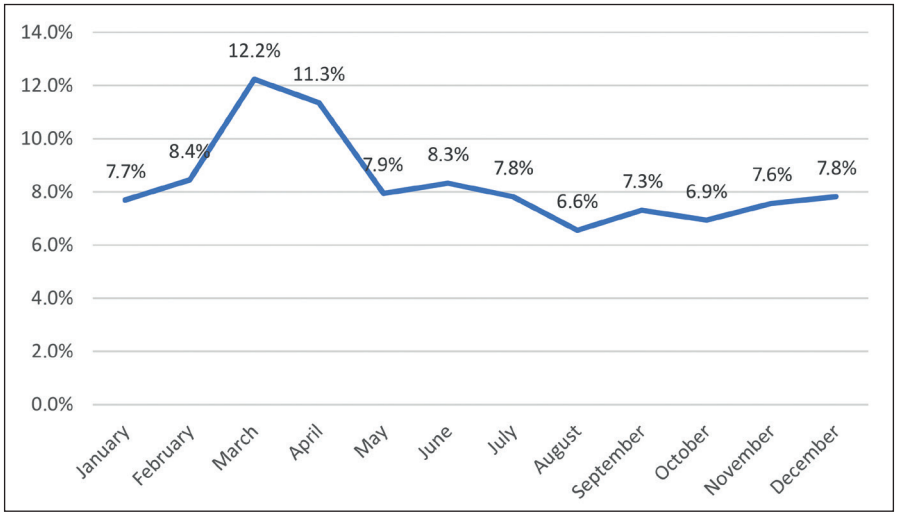

Figure 5. Seasonal phenology of raptor attacks. Percentage values represent the proportion of 201 interviewed fanciers, whose flocks were attacked in the given month

5. ábra A ragadozók támadásainak szezonális alakulása. A százalékos értékek a 201 megkérdezett galambtartó közül azok arányát mutatják, akiknek galambállományát az adott hónapban támadás érte

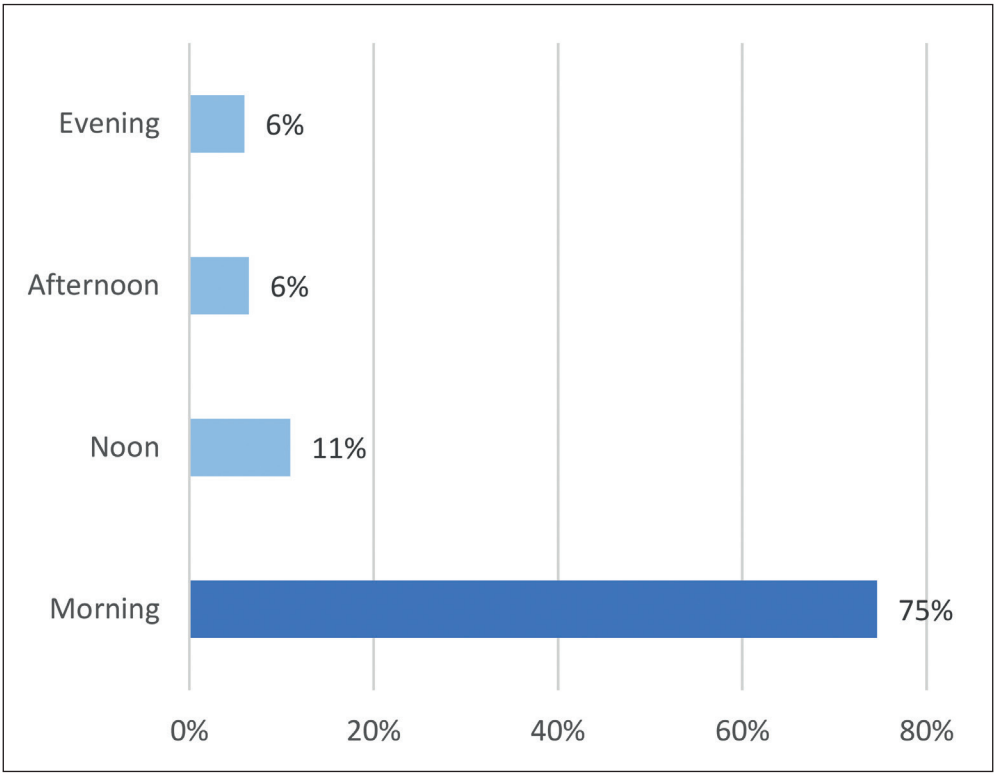

Figure 6. Daily phenology of raptor attacks, based on the answers of those out of the 201 interviewed fanciers, who suffered raptor attacks. Daytime periods: Morning (7:00–10:00), Noon (10:00–14:00), Afternoon (14:00–18:00), Evening (after 18:00)

6. ábra A ragadozómadár-támadások napi fenológiája, a 201 megkérdezett galambtartó közül azok válaszai alapján, akik ragadozó-támadásokat tapasztaltak. Napszakok: reggel (7:00–10:00), délelőtt (10:00–14:00), délután (14:00–18:00), este (18:00 után)

(≤ 5%). The reported average annual rate of pigeon loss during races was 30% (n = 6,007 pigeons lost) and for 13% (or 42% of all pigeons lost) of these, the fanciers blamed raptors. Most of raptor attacks were reported to take place in spring (March – April) *(Figure 5)*, in the morning hours *(Figure 6)* and were caused by hawks (*Accipiter* sp.) and falcons (*Falco* sp.) *(Figure 7)*.

Data from the GPS rings revealed that in 18% (n = 13) of the GPS-tracked flights pigeons were target of a raptor attack. In one of those cases, the pigeon was attacked at three different locations along 245 km long race flight, while in another case the pigeon was attacked twice along 217 km long race flight. In four cases (n = 72 tracked flights in total), the GPS ringed pigeons were lost, but there is no evidence this resulted from raptor attacks.

The GPS marked pigeons flew through three main regions in Bulgaria *(Figure 1)*, with predominance to Eastern (54% of the tracked flights), compared to Southern (37%) and Western Bulgaria (10%). However, just one of all raptor attacks took place in the east (in Romania), while all other attacks (12 attacks or 94%) took place in Western Bulgaria. The

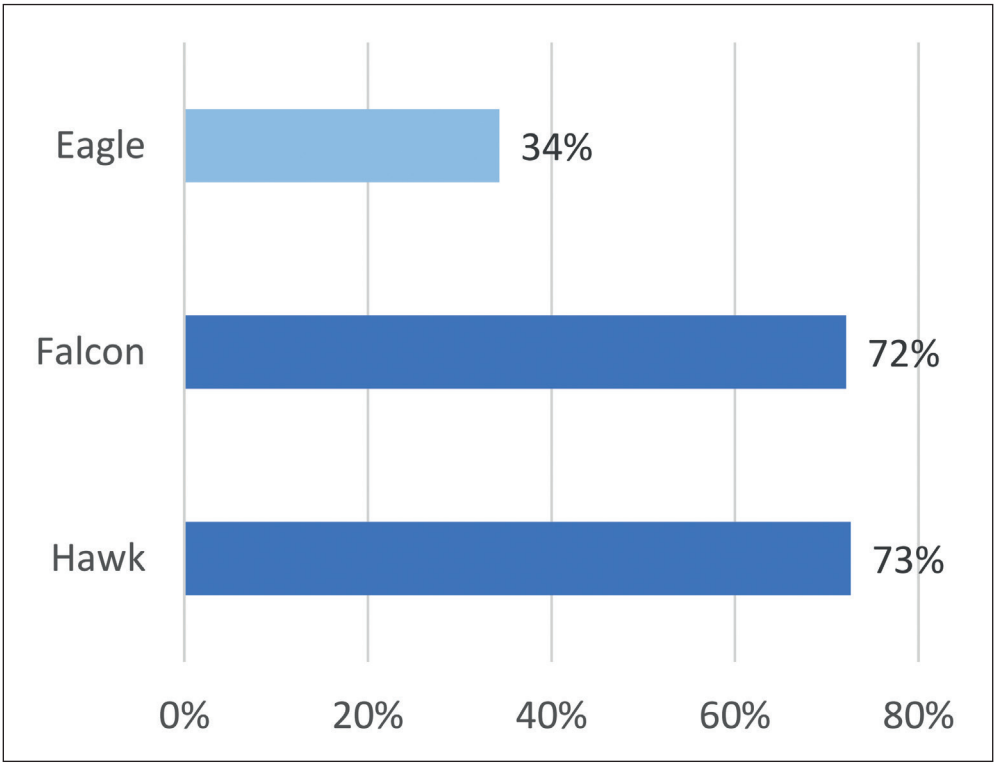

Figure 7. Ranking of raptor groups attacking the racing pigeons the most often, based on the answers of those out of the 201 interviewed fanciers, who suffered raptor attacks

7. ábra A versenygalambokat leggyakrabban támadó ragadozómadár-csoportok rangsora, a 201 megkérdezett galambtartó közül azok válaszai alapján, akik ragadozó-támadásokat tapasztaltak

elevation of attacks varied between 256 m a.s.l. and 1,534 m a.s.l. (962 m a.s.l. on average). Most raptor attacks took place along the final 1/3 of the race itinerary (11 attacks or 88%), in the upland (above 800 m a.s.l.) and in woodlands (81%).

Efficiency of preventive measures

For Bright-Colored Wing Patches method, the survival of anti-raptor spray-marked pigeons (77% survival; n = 1,080) was 16% higher compared to unmarked pigeons (61% survival; n = 1,393) *(Figure 8a)*. While this method showed some effectiveness, it cannot fully deter raptor attacks on pigeons, as 18 of the spray-marked pigeons (1.7%) returned home with injuries caused by raptors. These results were supported by fanciers' perceptions about the spray's effect: overall, 79% (n = 26) were satisfied, 36% (n = 12) expressing full confidence in the method; 18% (n = 6) could not judge if the method was efficient or not, and 3% (n = 1) considered the spray ineffective. For the Painted Eyespots method, fanciers reported an average 20% higher survival rate in eyespot-painted pigeons compared to the control *(Figure 8b)*.

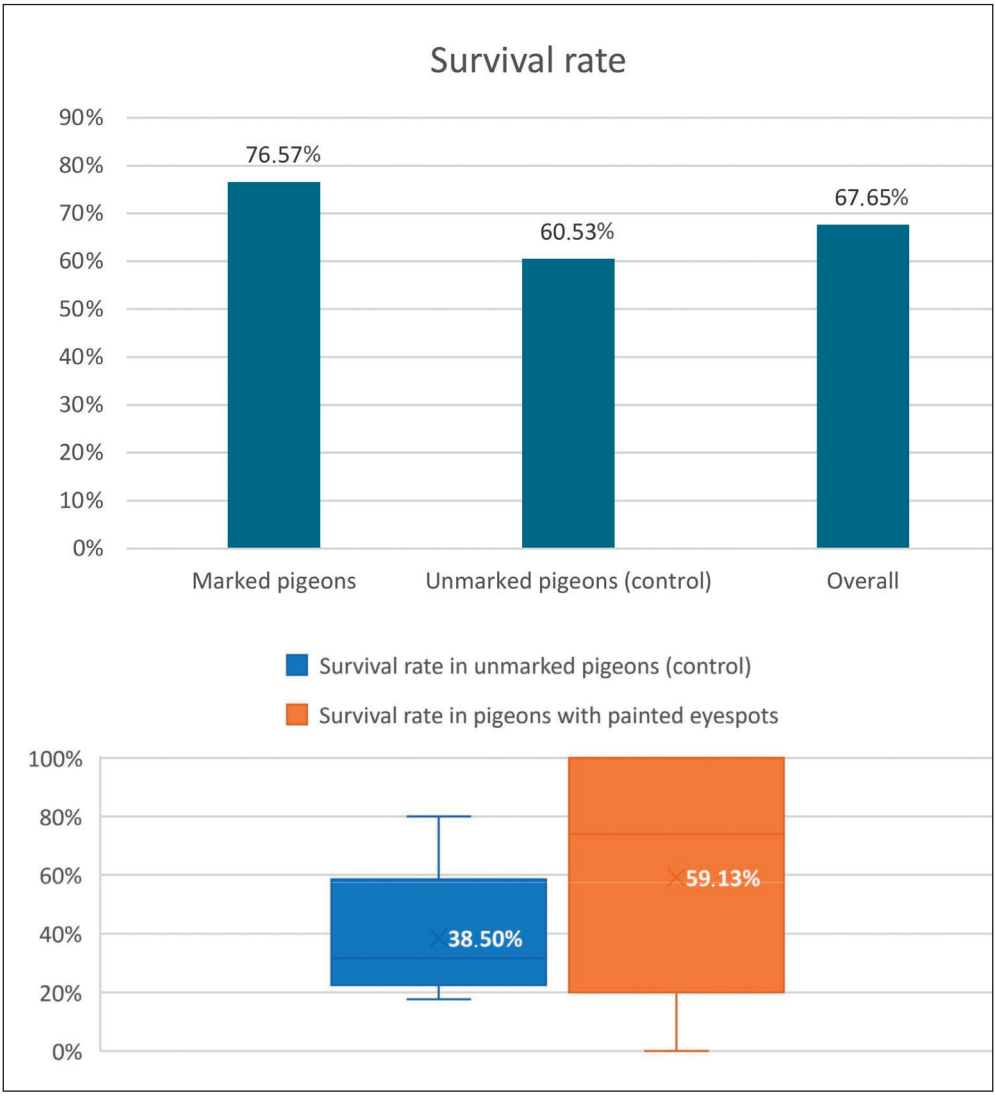

Figure 8. Comparison of the survival rates between: (a) *above*: marked pigeons (n = 1,080) with anti-raptor repellent spray and unmarked pigeons (n = 1,393) in the same flocks; (b) *bellow*: pigeons with painted eyespots (n = 72) and unmarked pigeons (n = 427) in the same flocks

8. ábra A túlélési arányok összehasonlítása: (a) Fent: ragadozómadár-riasztó spray-vel kezelt jelölt galambok (n = 1080) és ugyanazon csapatokban lévő, nem jelölt galambok (n = 1393); (b) lent: festett szemes galambok (n = 72) és ugyanazon csapatokban lévő, nem jelölt galambok (n = 427)

Discussion

Timing and location of raptor attacks

Our study shed light on the location and timing of raptor attacks on racing pigeons. The main known raptor predators for racing pigeons in Europe are the Peregrine Falcon *(Falco peregrinus)*, the Saker Falcon *(F. cherrug)*, the Eurasian Sparrowhawk *(Accipiter nisus)* and the Northern Goshawk *(A. gentilis)* (e.g. Shawyer *et al.* 2000, Henderson *et al.* 2004, Rutz 2004, Dixon *et al.* 2018, Panter & Amar 2021). According to Iankov *et al.* (2007), the European Sparrowhawk and the Northern Goshawk are more densely distributed in forested mountain and hilly areas, while the Peregrine population inhabits mainly mountain and semi-mountain regions in the country. This can explain the observed higher frequency of raptors attacks on pigeons in upland forested areas during our study. Although the re-introduction efforts since 2015, the Saker Falcon is still very rare in Bulgaria (Lazarova *et al.* 2021, Arkumarev *et al.* 2025), and thus, discussing any potential impact on domestic pigeons would be speculative. The higher frequency of raptor attacks on domestic pigeons in spring coincide with the breeding season of the raptors (Newton 1979). Likely, it is also related to the start of intensive training of homing pigeons in Bulgaria and in the most European countries *(pers. comm.)*, when large numbers of tossed pigeons start to cross the countryside offering „complementary" prey for raptors. The morning and evening peaks of falcons hunting activity are described by (Rejt 2001). The observation that the majority (88%) of attacks occurred along the last 30% of the race itinerary, when pigeons are likely more exhausted, highlights the vulnerability of racing pigeons during this critical phase of the flight. This finding emphasizes the need for targeted mitigation strategies to protect pigeons during the final stages of races, when they may be particularly susceptible to predation.

Effectiveness of preventive measures

The results of our study provide insights into the effectiveness of preventive measures aimed at mitigating raptor predation on racing pigeons. Bright-colored wing patches, applied using anti-raptor spray, showed some degree of effectiveness in increasing pigeon survival rates. The survival of spray-marked pigeons was 16% higher compared to unmarked pigeons, indicating a potential deterrent effect against raptor attacks. However, it is important to note that this method did not fully eliminate raptor predation, as some spray-marked pigeons returned home with injuries caused by raptors. Fanciers' perceptions of the spray's effectiveness varied, with a majority expressing satisfaction, though some remained uncertain or considered the spray ineffective.

Similarly, painted eyespots were found to contribute to increased survival rates among pigeons, with an average 20% higher survival rate reported compared to controls. While this method seemed more promising, variability in survival rates among fanciers and individual pigeon flocks suggests the need for further optimization and refinement. In a previous study conducted by Götmark (1994), creating bright-color patches on Common Blackbird *(Turdus merula)* wings has been proved to reduce predation risk by Northern Goshawks. However,

during the preliminary meetings with pigeon fanciers, we found quite contradictory opinions about the efficiency of anti-raptor spray: some fanciers believed it is very useful to minimize the losses, while others claimed it has no effect on raptor attacks. Few people even speculated it has an opposite effect by attracting raptors to pigeons. In contrast, the Codice LIVIA method, being used in Italian lofts to ward off hawks, has been documented to significantly reduce the fatal attacks (Federazione Colombofilia Italiana 2014). The natural eyespots markings evolved independently in many taxa as anti-predator signals (Ruxton *et al.* 2004). A classic example of anti-predator markings are eyespots on moth and butterfly wings (De Bona *et al.* 2015), but many other animal groups including other insects, fishes, mollusks, amphibians and birds use concentric circles to deter predators (Ruxton *et al.* 2004). The suggested mechanism behind the anti-predator effect for raptors (Balgooyen 1975, Negro *et al.* 2007) is that eyespots may deceive predators or 'mobbers' into perceiving they have been detected, thereby preventing an attack (the "detection hypothesis"). A successful experiment has been conducted in Africa, where artificial eyespots painted on cattle rumps have been evidenced to reduce attacks by large carnivores (Radford *et al.* 2020). In Scotland, the eyespots were used only as loft-based deterrent, but not as pigeon-based deterrent, with relatively high rate of positive feedback from pigeon fanciers (Henderson *et al.* 2004). All this is to say that factors such as color choice, placement, and individual variation in raptor response may influence the efficacy of this deterrent method.

Overall, these findings underscore the importance of evaluating and further refining preventive measures to effectively mitigate human-raptor conflicts in the context of racing pigeon sport. Further research is needed to optimize the application and effectiveness of these methods, taking into consideration factors such as color choice, placement, different combinations of methods, and individual variation in raptor response to enhance efficacy.

Potential biases and gaps in interpretation

Several potential biases and limitations should be considered in the interpretation of our results. Firstly, the results from the questionnaires represent the perceptions of pigeon fanciers which should be further tested to understand at what extend they meet the objective circumstances. However, from the more general perspective of the topic, we are discussing (i.e. human-raptor conflict), and specifically from the fancier's view-point, the presence or absence of scientific evidence as a background for their perceptions does not always reflect on the severity of the conflict (Benett & Dearden 2014, Benett 2016). Moreover, through grasping perceptions we can acquire insights into the rationales behind local endorsement or opposition to wildlife governance and management (Engen *et al.* 2019). Moreover, the effectiveness of preventive measures may also vary depending on factors such as local raptor populations, environmental conditions, and individual pigeon fancier practices. Additionally, the sample size and geographic scope of our study may limit the generalizability of results to other regions or contexts. Furthermore, the perception of effectiveness among pigeon fanciers may be influenced by factors such as individual experiences, biases, and preferences, which could introduce subjective biases into the data. Future research should aim to address these limitations by incorporating larger sample sizes (also allowing to

analyze the impacts considering different types of pigeons), wider geographic scope, and interdisciplinary approaches to better understand the dynamics of human-raptor conflicts from the perspective of pigeon racing and inform conservation strategies.

Inferences for conservation

Our study underscores the importance of engaging with the pigeon fancier's community as a key stakeholder group in successful raptor conservation programs. The effective collaboration with the Bulgarian pigeon fanciers' community played a pivotal role in acquiring data on pigeon losses attributed to birds of prey. By engaging with various racing pigeon organizations at local and national levels, BSPB (BirdLife Bulgaria) fostered collaborative partnerships and conducted multiple working sessions with local clubs, associations, and federations. This approach facilitated the collection of valuable data and ensured that the perspectives and expertise of pigeon fanciers were integrated into the study design and implementation process.

The findings of our study have important implications for understanding and addressing human-wildlife conflicts, particularly in the context of racing pigeon sport. By quantifying the impact of raptor predation on racing pigeons and testing preventive measures, our study highlights the complex interplay between human interests and wildlife conservation. While raptors are protected under various conservation laws and regulations, conflicts with human activities, such as racing pigeon sport, continue to pose challenges for conservationists. Effective mitigation strategies, informed by scientific research and stakeholder engagement, are essential for promoting coexistence between humans and raptors.

Understanding the phenology of raptor attacks provides valuable insights for adapting pigeon training regimes to minimize losses. Our findings provide novel insights into the effectiveness of preventive measures aimed at mitigating raptor predation on racing pigeons in Bulgaria. Additionally, we evidenced that the use of painted eyespots has good potential as a deterrent against raptor attacks in the context of racing pigeon sport. Our study revealed higher pigeon survival rates among fanciers who apply prevention measures compared to those who do not, but it is essential to acknowledge that mitigation measures such as anti-raptor spray and painted eyespots are not panaceas. While they show promise in decreasing raptor predation, they cannot eliminate it entirely. Therefore, promoting the application of these measures among pigeon fanciers should be encouraged, with realistic expectations communicated to avoid exacerbating human-raptor conflicts. Further research is warranted to deepen our understanding of raptor predation on racing pigeons. Direct assessment of mortality rates and more extensive experimental studies on the efficacy of different mitigation measures are needed to inform evidence-based conservation strategies. Specifically, repeating experiments on painted eyespots with larger sample sizes and broader participation of pigeon fanciers could yield valuable insights into the effectiveness of this method. Additionally, fostering better awareness, communication, and collaboration between authorities, environmental NGOs and pigeon fancier organizations is imperative for softening human-raptor conflicts. Producing guidelines for pigeon fanciers, outlining the best-known mitigation practices, can serve as a useful tool in this regard. By working

together and sharing knowledge and resources, we can strive towards a more harmonious coexistence between racing pigeons and raptors, ensuring the sustainability of both wildlife and human activities.

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