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Human activities can hinder the breeding of a top avian predator: preliminary results

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Abstract The Eastern Imperial Eagle (EIE) is a large-sized, globally threatened species with a wide distribution. The species is extremely vulnerable and sensitive to human disturbance and activities in the vicinities of its nests. We analyzed the effect of human disturbance in two territories of Eastern Imperial Eagles from Bulgaria in 2008–2009. We recorded 375 cases of different types of human activity in the vicinities of the two surveyed nests – 60 cases in nest A and 315 in nest B. The most common activity around the studied nests was the passing of light motor vehicles (n=100 cases). Our results highlight that the probability of EIE's reaction is dependent on the type of activity, distance from the nest and the duration of the activity. However, eagles' reaction is independent from the number of intruders. We found that with the decrease of the distance to the nest, the reaction progresses and is more acute. We found statistical differences between the distance belts and the majority of alert and flight reactions that were recorded at distances up to 300 m from the nests. We reported that humans walking around nests (mainly hunters, fishermen, tourists, people illegally extracting sand in the close vicinities of the nests) result in a large number of reactions of flight off by the eagles thus, leaving the nest unattended. More research on a large scale on this topic is needed including more accurate measures to address human disturbance in EIE territories. The findings will be applied to ensure higher breeding rates and species conservation.

Keywords: Eastern Imperial Eagle, Bulgaria, disturbance, breeding, alteration, population

Összefoglalás A parlagi sas nagy testméretű, globálisan veszélyeztetett, széles elterjedési területtel rendelkező madárfaj, amely rendkívül érzékeny a fészke közelében végzett emberi tevékenységekre, zavarásra. A vizsgálatban ez utóbbiak hatását elemeztük Bulgáriából származó parlagi sasoknál, két területen 2008–2009-ben. A két vizsgált fészek környezetében 375 különböző típusú emberi tevékenységet rögzítettünk – 60 esetet az A, és 315-öt a B fészeknél. Ezek közül a leggyakoribb a könnyű gépjárművek áthaladása volt (n=100 eset). Eredményeink rámutatnak arra, hogy a parlagi sasok reakciója függ a tevékenység típusától, időtartamától és a fészektől való távolságtól, nem függ azonban a „betolakodók" számától. Megállapítottuk, hogy a fészektől való távolság csökkenésével a sasok reakciója egyre hevesebb. Statisztikai különbségeket találtunk az egyes távolságokra levő zónák, illetve a legtöbb riasztási és repülési reakció között, amelyeket a fészkektől legfeljebb 300 m-es távolságban rögzítettünk. Beszámoltunk arról, hogy az emberek (főleg vadászok, halászok, turisták, földmunkások) a fészkek körül járva gyakran zavarják fel a sasokat, így a fészkek sokszor felügyelet nélkül maradnak. A témában további, nagyobb léptékű kutatás szükséges annak érdekében, hogy a parlagi sasok elterjedési területein az ember okozta zavarás hatásait megfelelő intézkedésekkel ellensúlyozni lehessen. A kutatások eredményeit felhasználva biztosítható a parlagi sasok magasabb szaporodási aránya, illetve a faj megőrzése.

Kulcsszavak: parlagi sas, Bulgária, zavarás, költés, változás, populáció

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Introduction

The Eastern Imperial Eagle *(Aquila heliaca)*, hereafter EIE, is a long-lived, large-sized territorial raptor with a wide range spanning from Central Europe and the Balkans to South Siberia, China and Mongolia (BirdLife International 2021). The species global population is estimated to exceed 10,000 mature individuals (BirdLife International 2021), whereas its European population is estimated to 1,800–2,200 pairs during the period 2000–2010 (Demerdzhiev *et al.* 2011a). EIE faces severe threats, such as high adult and juvenile mortality due to persecution, poisoning, and hazardous powerlines, therefore the species is listed as vulnerable on a global scale (BirdLife International 2021). In Bulgaria, the EIE was a widespread species in the past (Patev 1950). Recovery of the population started from 2000 onwards and the species gradually increased reaching 35–40 pairs nowadays (authors data), distributed mainly in the southeastern part of the country (Demerdzhiev *et al.* 2014).

Human activities have severely affected biodiversity and raptor populations worldwide (Heath & Evans 2000, McClure *et al.* 2018). In this respect, numerous studies explore the relationship between human activities and their effect on various breeding rates in birds and raptors (White & Thurow 1985, Jenny 1992, Watson 1994, McGrady 1997, Ruhlen *et al.* 2003, Ruddock & Whitfield 2007). Human activities in the close vicinity of the nest during incubation and early stages of chick development can alter breeding in raptors (Grier & Fyve 1987, Grubb *et al.* 1992, Holmes *et al.* 1993, Steidl & Anthony 1996, Richardson & Miller 1997, Swarthout & Steidl 2001). Disturbance of breeding birds can increase energy costs and decrease hunting success and/or lead to abnormal distribution of nest attendance (Grier & Fyve 1987). Moreover, human disturbance can affect also parental care in various dimensions (Fernandez & Ackona 1993, Verhulst *et al.* 2001, Bautista *et al.* 2004), although behavioral response varies individually (Richardson & Miller 1997). Various studies from Spain have found a considerable negative effect of human activities over the demography of the Spanish Imperial Eagle *(Aquila adalberti)* (hereafter SIE) (Gonzalez *et al.* 1990, Gonzalez *et al.* 1992, Ferrer & Harte 1997, Bisson *et al.* 2002, Gonzalez *et al.* 2006). Results show that habitat selection and breeding success are affected by urbanization (for example distance from the nearest settlement) and inaccessibility of the breeding territories to humans that suggests that the SIE avoids disturbance (Gonzalez *et al.* 1992, Castano & Guzman 1995). As a result of the surveys conducted in Spain, some authors recommended a ban of human activities in a radius of 500–800 m around nests of Spanish Imperial Eagle during the breeding season (Gonzalez *et al.* 2006). Contrastingly, such measures might not improve fecundity and lead to a negative attitude towards eagles. Thus, others argue that the acquaintance of the SIE to human disturbance might increase the potential breeding habitat and adult survival of the species and improve its plasticity and tolerance to humans (Ferrer *et al.* 2007).

Studies on human disturbance and its effects on the breeding rates of the EIE are scarce. However, human disturbance was listed as one of the main threats for the EIE in Bulgaria, altering species breeding rates, especially in plain areas (Demerdzhiev *et al.* 2011a). A survey that analyses the effects of urbanization, transport and power lines over the current and potential distribution of the EIE in the Pannonian Plain, suggests that eagles avoid human activities at a certain distance and that settlements are the most important factor in terms of territories selection and establishment (Horváth *et al.* 2009).

In Bulgaria, the impact of human activities on EIE's behavior in the breeding season is barely studied, not quantified, except for some characteristics of parental care (Dobrev 2009). Based on the considerable changes in species breeding and foraging habitats, the conservation status of the EIE and species vulnerability to habitat alterations (Demerdzhiev *et al.* 2011a, Demerdzhiev *et al.* in press), a detailed study on the relationship between human activities and the response of the EIE is needed. The current study aims to reveal the impact of different human activities on the reactions of the EIE in the breeding season and investigate the tolerance of the species towards such disturbances, giving a first preliminary assessment. Hence, we set the following objectives: (1) to reveal the most common human activities and their magnitude in EIE territories; (2) to define and measure eagle's reactions and (3) suggest primary conservation measures to avoid disturbance and nest/clutch abandonment.

Materials and Methods

Study area

The study was conducted in the Sakar Mountain, Bulgaria. This is a low-mountain region landlocked in the southeastern corner of the country *(Figure 1)*. The area is characterized by a continental-Mediterranean climate. It contains patches of mixed deciduous forests of several oak species (*Quercus* sp.) and oriental hornbeam *(Carpinus orientalis)*, agricultural areas, pastures and open areas overgrown with shrubs of Jerusalem thorn *(Paliurus spina-christi)*, and xerothermic grass communities (Bondev 1991).

Survey design

Observations were carried out in April–July during the period 2008–2009. We monitored three breeding attempts of two EIE pairs during the breeding season, 20% of the species population in the studied area (n=10) (Demerdzhiev *et al.* 2011a). Observations lasted between 7.00 and 20.00 h each monitoring day (n=67) and were performed from vantage points at a distance of around 1,000 m from the nest using binoculars 10x50 and spotting scopes 20x60 (Bibby *et al.* 1999). To avoid disturbance, alarming the birds and register species natural reactions, we followed recommendations of Gonzalez *et al.* (2006) and Zuberogoitia *et al.* (2008). Birds were not provoked to study their reactions (White & Thurow 1985). The age of the partners within each pair was determined following Forsman (2005). Pair A consisted of fully adult birds, whereas in pair B, the male partner was fully adult in sixth plumage, while the female was in fifth plumage. During the second year, however, pair B consisted of the same female in its sixth plumage and a new male in fifth plumage, because of a replacement within the pair. Observations covered the period from the laying of the eggs until fledging. For each breeding attempt, we differentiated two periods:

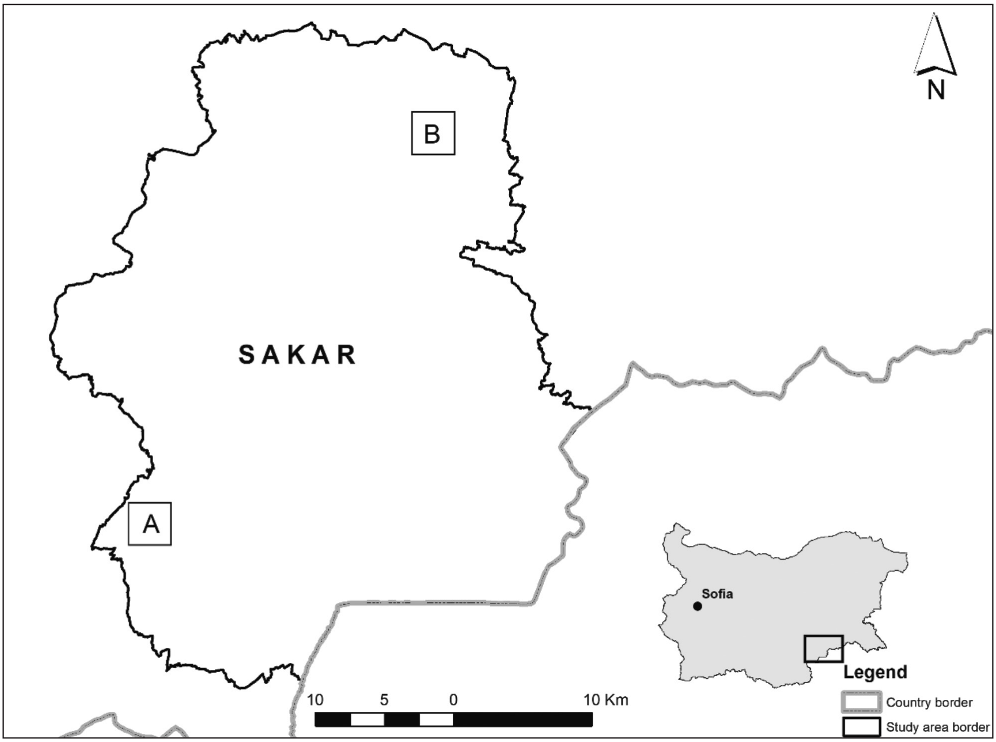

Figure 1. Location of the study area and the surveyed nests A and B
1. ábra A vizsgálati terület és a vizsgált fészkek (A és B) elhelyezkedése

(a) incubation (from the laying of the first egg until hatching of the first chick) and (b) chick rearing period (since the hatching of the first egg until fledging).

We recorded and categorized human activities to assess their quantity, magnitude and impact on the reactions of the species when they occurred in the vicinity of the nests. Whenever such activity occurred less than 1 km of the nest (Gonzalez *et al.* 2006), we recorded the following information: (1) exact starting time, (2) type and (3) duration of the activity, (4) linear distance to the nest, (5) number of people or vehicles involved in the activity and (6) the eagles' response. The type of activity was defined according to the following seven categories: A1 – light vehicles (cars, 4wd cars, microbuses, motorcycles); A2 – agricultural machinery (tractors, reaping machines); A3 – freight motor vehicles (trucks, buses); A4 – non-mechanized vehicles (carriages, bicycles); A5 – illegal, small quarries for sand extraction around nests; A6 – locals and/or shepherds regularly present in the area; A7 – casual people non-regularly present in the area (hunters, fishermen). The duration of the activity was categorized into the following time intervals: T1 (short-term activity) – 1–2 min; T2 (medium-term activity) – 3–10 min and T3 (long-term activity) – over 10 min. The linear distance to the nest was categorized into the following distance belts: 0–100 m; 101–300 m; 301–500 m and over 500 m (Ruddock & Whitfield 2007). The number of people or vehicles involved in the activity where: N1 – single people/vehicles and N2 – groups of two and/or more people/vehicles.

The reaction of the birds was categorized as follows: (NR) No reaction, whenever birds do not react to the particular activity; (AR) Alarm reaction, whenever a bird changes its behavior, is abused by the activity and exhibits alarming signs (staring, head signals) without leaving the nest unattended; (FR) Flight reaction when the bird is scared away and leaves the nest. We further measured the intrusion frequency, calculated as the ratio of the total number of human activities registered for each breeding attempt to the total number of observation days (Gonzalez *et al*. 2006).

Statistical procedures

Data were analyzed using Statistica for Windows, Release 10.0 (Statsoft Inc 2011). We employed descriptive statistics to calculate the observation time where means are presented ± Standard Deviation (SD). We used Break down & one way ANOVA to study the effect of different human activities on the reactions of the eagles. We set the reaction of the birds as a dependent variable and the number, the distance, the type and the duration of the activities as predictor variables. All tests were considered significant when $p \leq 0.05$.

Results

During our study, we spent 672.15 h of observations (192±17 h for nest A and 480±10 h for nest B). The observation time during incubation for nest A was 104.65±2 h and 87.35±3 h during the chick-rearing period. We observed nest B for 273.15±5 h during incubation and for 207.05±6 h during the chick-rearing period. We recorded 375 cases of different types of human activity in the vicinities of the two surveyed nests. The majority of the activities were recorded during the chick-rearing season (n=335, 89%) and the rest during incubation (n=40, 11%). We recorded 60 activities in nest A and 315 in nest B. The most common activities around the studied nests were A1 (n=100 cases, 26.6%), A6 (n=96, 25.6%) and A4 (n=85, 22.7%). In 2008, the intrusion frequency for nest A was 1.46 and 6.35 for nest B. In 2009 the intrusion frequency for nest B was 10.4.

In 313 cases (83%) we did not record any reaction of the eagles. Whilst, in 40 cases (11%) eagles showed signs of alarming reaction towards the given activity and in 22 cases (6%) eagles left the nest without attendance because of it. Our results highlight that the probability of reaction in the EIE is dependent on the type of the activity ($F=10.09$, $P=0.002$), distance from the nest ($F=8.39$, $P=0.004$) and the duration of the activity ($F=7.29$, $P=0.007$). Our results show that eagles' reaction is independent from the number of intruders ($F=0.00$, $P=0.99$).

We registered a statistical significance of the reactions of the eagle towards locals (A6) ($t=-5.15$, $P<0.0001$) and casual people (A7) ($t=28.88$, $P<0.0001$). We found that humans walking around nests (mainly hunters, fishermen, tourists, people illegally extracting sand in the close vicinities of the nests) result in a large number of reactions of flight off thus, leaving the nest unattended. We, however, noted that EIE could adjust to local people and routine activities as an adaptation to breeding successfully, especially in highly intensified agricultural fields and rural areas.

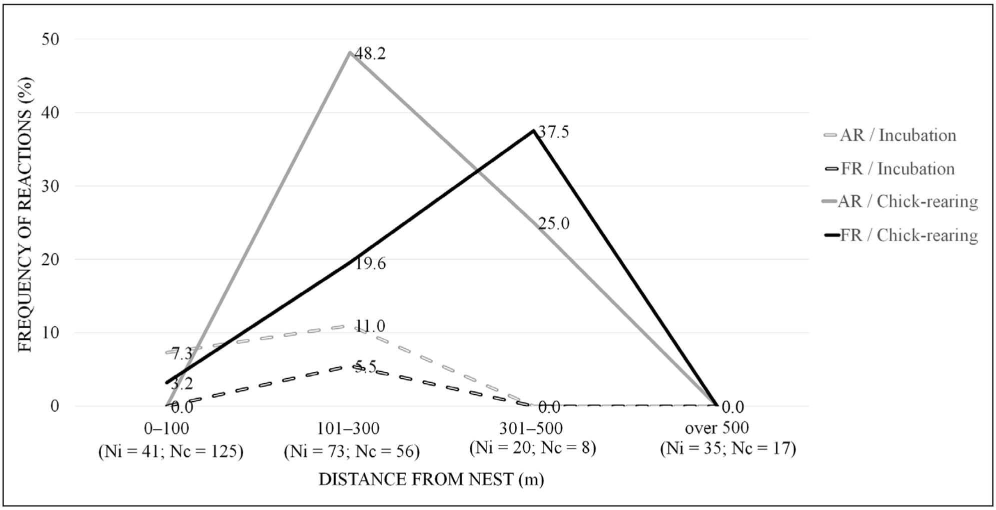

Figure 2. Frequency of alert (AR) and flight reactions (FR) caused by human activities according to their distance from the nest and breeding stage. Number of registered human activities in the different distance belts during incubation (Ni) and chick-rearing (Nc) are indicated respectively in brackets

2. ábra A riasztási (AR) és repülési reakciók (FR) aránya az emberi tevékenység hatására a fészektől való távolság és a költési stádium függvényében. A regisztrált emberi tevékenységek száma az egyes távolsági kategóriákban a kotlási (Ni) és a fiókanevelési (Nc) időszakokban zárójelben található

Eagles start to respond to any intruder when it approaches at distances of 301–500 m from the nest. However, we found that with the decrease of the distance to the nest, the reaction progresses and its frequency is most pronounced at a distance belt 101–300 m ($t=-2.66$, $P=0.008$) when the majority of the reactions were registered during incubation and chick-rearing period ($n=50$). At this distance, we recorded 5.5% of the flight reactions during incubation ($n=4$) and 19.6% of the flight reactions during the chick-rearing period ($n=11$). At distance 301–500 m, we recorded 2 alert reactions (25%) during chick-rearing period and 3 flight reactions (37.5%). We did not register reactions at distances greater than 500 m *(Figure 2)*.

Discussion

Human disturbance to wildlife is a growing topic of concern that can deviate animals from their normal behavior and result in different biological and ecological responses (Martínez-Abraín *et al.* 2010, Pauli *et al.* 2016). We recorded a significant number of human activities in the close vicinities of the nests whereas passing cars accounted for the majority of the cases. Similar results of numerous human activities in the vicinities of eagles nests were reported from Spain where more than 2,000 observations of different activities were recorded (Gonzalez *et al.* 2006). This can be explained by species ecology, inhabiting open and human-managed landscapes, namely arable lands, pastures and rural areas in general. Hence, some authors suggested that habituation of breeding pairs to human activities can potentially increase species nesting habitat in the human-dominated landscapes (Ferrer *et al.* 2007).

We found a statistical significance of the reactions of the eagle towards humans walking around nests (mainly hunters, fishermen, tourists) that resulted in a large number of reactions of flight off. The most common characteristics of such people are the lack of a behavioral model. They stop at random positions, spend different times not moving or staring doubtfully. Such behavior is untypical for eagle-known models of routine activities, for example, by shepherds or vehicles that simply cross the territory, in a discrete interval of time during similar day hours, etc. (Gonzalez *et al.* 2006). Human disturbance of bird species (Fernandez-Juricic 2002) can urge birds to occupy lower quality territories (McGarigal *et al.* 1991), decrease nest attendance time (Martínez-Abraín *et al.* 2010) or compromise breeding (Zuberogoitia *et al.* 2008, Zuberogoitia *et al.* 2014). Some authors found that EIE responds to long-term disturbance by selecting nesting habitats away from human infrastructures (Gonzalez *et al.* 1992, Bisson *et al.* 2002, Horváth *et al.* 2009). In our study, light vehicles were the most frequent in EIE territories, similarly to the SIE (Gonzalez *et al.* 2006). We did not record any reaction of the eagles to this activity, but also towards non-mechanized vehicles and agricultural machinery. These types of activities are familiar and temporally predictable around nests (passing periodically, tilting, mowing, sowing). Nevertheless, they can affect eagles when they are executed very close to the nests and/or last long.

We did not find any relationship between the number of intruders and eagles' reaction. Conversely, a study from Spain revealed that the more people are involved, the stronger the reaction of the eagles was (Gonzalez *et al.* 2006). A larger number or groups of people would be easily spotted by the eagles at a greater distance. However, even a single person can disturb eagles when approaches too close to the nest similarly to a group of people, which might explain the lack of significance in our study. Nonetheless, the popularity of countryside tourism and rural areas among people living in urbanized areas is growing (Martínez-Abraín *et al.* 2010, Perona *et al.* 2019). As a result, the concentration of people during weekends and holidays might become an issue in some of the EIE territories in the future, considering also the species distribution in Bulgaria (Demerdzhiev *et al.* 2011b).

Our results are in agreement with previous studies in terms of the average reaction distance in the Golden Eagle *(Aquila chrysaetos)* (Holmes *et al.* 1993), the SIE (Gonzalez *et al.* 2006) and the Bald Eagle *(Haliaetus leucocephalus)* (Stalmaster & Newman 1978, Fraser *et al.* 1985, Grubb & King 1991, Steidl & Anthony 2000, Fernandez-Juricic 2002). In SIE, the average alert distance was 252 m (range 50–580), and the average flight distance was 261 m (Gonzalez *et al.* 2006). Golden Eagle exhibits alarming reaction at 400 m during incubation and at 625 m during chick-rearing period. The species leaves the nest at an average distance of 225 m during incubation and 400 m during the chick-rearing period (Ruddock & Whitfield 2007). These results confirm that a minimum of 250–300 m is required to buffer species reactions. Moreover, this implies that similar to other raptor species, the EIE, can detect hazards without showing any signs of a reaction. Therefore, early alarming reactions (before the flight of the bird) can remain unnoticed by the observer until the human activity is close enough to provoke the eagle to take off (Gonzalez *et al.* 2006). Based on our findings and other studies, we suggest that significant and/or regular human activities likely to cause frequent flight reactions from the nests of the EIE should be restricted at around 500 m to all active nests as a precaution measure during the breeding season. Nevertheless, such decisions must be considered cautiously and accommodated individually to every pair to avoid unnecessary negative reactions from the local communities (Ferrer *et al.* 2007, Zuberogoitia *et al.* 2014).

In the current survey, we found a statistically significant dependence between the reaction of the eagles and the duration of the activity in all time frames. We found that eagles react to some activities that last short, however, are unfamiliar an unusual to the eagles. For example, casual people, tourists, motorcycles that pass quickly through the territory but are not a routine around the nest. This is in contrast with the duration of activities that are not random, but regular around nests (for example ploughing, shepherds passing) but eagles are prone to them and recognize it. Therefore, eagles would react stronger to sudden and not typical activities around nests as a response to the long-term persecution from humans (Bijleveld 1974).

We recommend further and detailed research on this topic where the effect of different human activities is assessed to breeding success, productivity, age of birds and occupancy in much broader population scale. Thereby, a more robust estimate on human activities and their impact will be received and precise conservation measures (nest-guarding, adaptive management, restriction zones, etc.) might be applied accordingly at each territory.

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