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Preliminary study on the tolerance to human disturbance of Eagle Owl *(Bubo bubo)* in an active quarry in NW Hungary

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Abstract Population of the Eagle Owl *(Bubo bubo)* has been increasing in Europe including Hungary. The species occupy new habitats beside its ancient territories including quarries and buildings. This may result in conflicting conservation and economic interests in active quarries. Because eagle owls are strictly protected in Hungary, human activities around known nest sites require environmental permits. We aimed to obtain information on Eagle Owl behaviour in an operating quarry by tracking an adult female to base a future species-specific guideline to issue environmental permits for mining in quarries. We used a combined GPS-GSM and VHF telemetry. We found that the tracked female did not breed in the study year but remained in her home range during the study period. By studying her seasonal and daily patterns of movements, we found that she was not disturbed by regular human activities under the nesting cliff, but she was more sensitive to unexpected non-regular disturbance. Based on the satellite-tracking data, this specimen used an approximately 18 km^2 home range during the study period.

Keywords: telemetry, tracking, human activity, environmental permit, species-specific guideline

Összefoglalás Az uhu *(Bubo bubo)* állománya emelkedőben van Európában, ahogy Magyarországon is. A faj egykori élőhelyei visszafoglalása mellett új élőhelyeket is birtokba vesz, beleértve kőbányákat és épületeket is. Ennek eredményeképpen a működő kőbányákban konfliktusok alakulhatnak ki a természetvédelmi és gazdasági érdekek között. Mivel a faj Magyarországon védett, a revírben történő emberi tevékenységekhez környezetvédelmi engedély szükséges. Célunk az volt, hogy nyomkövetés segítségével információkat gyűjtsünk egy öreg tojó uhu viselkedéséről egy működő kőbányában, hogy megalapozzunk egy, a későbbiekben elkészítendő, fajspecifikus útmutatót a kőbányák működésére vonatkozó környezetvédelmi engedélyek kiadásához. Egy kombinált GPS-GSM és VHF alapú eszközt használtunk. Utóbbi jeleit egy automata vevőegység rögzítette folyamatosan, a nap 24 órájában. A VHF adó jeleit kézi vevőegységgel is lehetett fogni. A pár nem költött a vizsgált évben, de a vizsgált időszakban folyamatosan a revírben volt. A szezonális és a napi mozgásmintázatok elemzése azt mutatta, hogy a fészek alatt végzett rendszeres emberi tevékenység nem zavarta, azonban sokkal érzékenyebben reagált a nem várt, nem rendszeres zavarásra. A műholdas nyomkövetés adatai alapján az uhu egy megközelítőleg 18 km^2 kiterjedésű területet használt a vizsgált időszakban.

Kulcsszavak: telemetria, emberi tevékenység, környezetvédelmi engedély, fajspecifikus útmutató

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Introduction

Although global population of Eagle Owl (*Bubo bubo* Linnaeus, 1758) appears to be declining, the European population has undergone a continuous increase in the last decades (BirdLife 2018). Accordingly, population of Eagle Owl has increased in Hungary *(Figure 1)* gradually re-occupying the former habitats of the species (Firmánszky *et al.* 2004, 2005, Petrovics 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015). The increase of the European population is not without conflicts. As an apex avian predator, almost all bird and mammal species are on the diet of Eagle Owls including rare and protected ones (Lourenço *et al.* 2011). Accordingly, Eagle Owls regulate also population sizes and distribution patterns of other birds of prey species through intraguild predation (Mikkola 1976, Gainzarain *et al.* 2000, Sergio *et al.* 2004, 2007, 2008, Brambilla *et al.* 2006, 2010, Martínez *et al.* 2008, Lourenço *et al.* 2011).

Eagle Owls generally prefers habitats at lower altitude with open space in proximity of nest. They do not build nest, they usually lay eggs on cliff ledges or in stick nests of other bird species. Therefore, their most favoured nests sites are natural rock formations and quarries, but they may also breed in riparian forests, as well as on loess ledges (Firmánszky *et al*. 2004, Petrovics 2007). The Eagle Owl is known to tolerate human presence and nests not only near human settlements (Marchesi *et al.* 2002, Martínez *et al.* 2003, Cochet 2006, Petrovics 2007), but also started to colonize buildings in cities (Harms 2016). Quarries play an important role in this respect. For example, in Germany, quarries – both actively mined as well as inactive quarries used for leisure activities – are the most important breeding sites for Eagle Owls (Lindner 2005).

Human – Eagle Owl conflicts arises especially in active quarries, where conservation and economic interests meet, and disturbance resulted from human activities may jeopardize

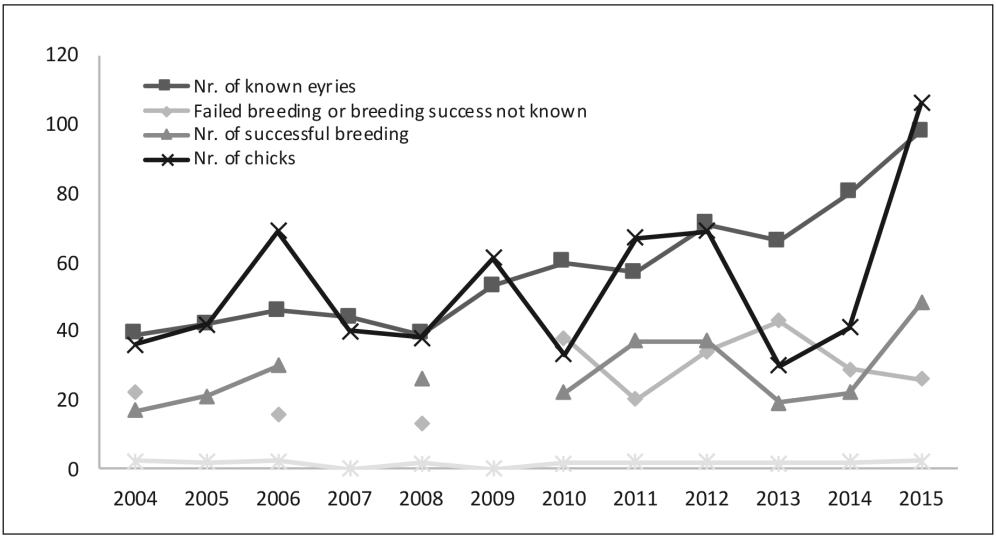

Figure 1. Population trend of the Eagle Owl in Hungary
1. ábra Az uhu állományának alakulása Magyarországon

breeding success. Disturbance caused by human activities can be manifold from economic activities (e.g. mining operations like extraction and crushing), through road or air traffic, hiking, rock climbing, walking dog, as well as targeted disturbance like birdwatching. It is desirable therefore to take preventive measures to support breeding success of this protected bird of prey species.

The international conservation status of the Eagle Owl is "*Least concern*" (BirdLife 2018). It is listed in CITES Appendix II., Bern Convention Appendix II and European Union's Birds Directive Annex I. and protected also by national legislation in most countries within its range (BirdLife 2018). In Hungary, Eagle Owl falls in the "*strictly protected*" category as defined in general by the Law 1996. LIII. "*on the conservation of nature*" and specified in the annex 3. of the decree 13/2001 (V.9.) listing the species under legal protection. It is necessary therefore, to obtain environmental permits for any activity including economic ones that can have potentially negative effect on the life activities of Eagle Owls. As for mining in quarries, permits usually define seasonal restrictions to prevent disturbance of breeding pairs. There is however, no guidelines for regional authorities, on how to set the restrictions to reach a mutually beneficial compromise between successful breeding and economic activities. As a result, different regional authorities in Hungary prescribe different restrictions ranging from fairly weak to unnecessary strict ones. None of those extremes will be beneficial for the owls on long term. Well-designed restrictions however, will result in conservation benefit for the species.

The main goal of the study was to evaluate the response of Eagle Owls to human disturbance in an active quarry in Hungary by radiotracking an adult female Eagle Owl with a combined GPS-GSM and VHF device. We also aimed to map her home range. The hypothesis was that the tracked Eagle Owl nesting in the quarry would tolerate disturbance resulted from everyday mining activities, also remaining in their nest or cliff perch in the quarry even during the day. However, she will respond negatively to unusual or targeted disturbances. We also assumed that the bird will be in the home range throughout the year and her movements likely remain within a few kilometres.

Material and methods

The first phase of the study was carried out near Esztergom, Hungary in a limestone quarry owned and managed by COLAS Északkő Ltd. The quarry has been used by Eagle Owls since 2004. The quarry is about 3.8 ha and an approximately 50 m high cliff closes the northeast side of the yard. The border of Pilis-Visegrádi Mountains Natura 2000 site runs on the top of the quarry. The cliff itself has not been permitted to be mined in the last two decades partly due to conservation considerations. The main cliff of the quarry faces to southwest offering a good view on an open landscape with a mosaic of grasslands, arable lands, vineyards, gardens and patches of bushes and wood. Extensive forests from northeast reach the top of the cliff and cover the top of the range to which the quarry belongs. The village of Kesztölc is located southeast of the quarry within only a kilometre. A major road, a lake and a covered landfill site can be found west – southwest of the quarry within only 3 kilometres.

The ownership of the quarry changed several times through the years and mining activities were ceased in some years. In 2016, when the field work was done, the quarry was active. Limestone extraction was done in the yard under the cliff but crushing and classifying was done further away, outside of the yard. The equipment and the yard were guarded permanently. Outside of working hours, guards on duty had to walk around the yard and check the equipment once in every hour also in the night. All work activities or extraordinary events occurred in the mine was registered in a book, which was our source of background information to compare against data from the owl's VHF transmitter.

In 2016, we trapped the adult female of the pair before the start of the breeding season to mount her with tracking devices. We used bow net for trapping as described in other studies (Leditznig 1992, Hull & Bloom 2001, Barclay 2008). After successful trapping, we mounted the Eagle Owl with a combined GPS-GSM and VHF device by using Teflon ribbon harness similarly to other studies (Delgado *et al.* 2009). The tracking equipment formed a rucksack on the bird, not preventing her from activities like hunting or mating.

The devices consisted of two attached, but otherwise separately functioning units. The GPS-GSM unit was a 45 gram, solar powered "*Crane*" type logger manufactured by Ecotone Telemetry. Crane loggers were designed with large backup batteries for birds mostly active in poor light conditions or with extreme large feathers (covering the solar panel). The unit can be programmed via an online panel and capable to locate the bird in every half an hour in good light conditions. Data is transmitted to the online panel via GSM network after every fourth successful GPS localization. Supplementary data as battery status, temperature, activity, and GSM network level are also recorded and transmitted. The accuracy of built-in GPS is a few metres in open areas, but worse in covered places. In our study, we set the localization frequency to one GPS record per night to save battery.

We attached a 10-gram VHF unit to the logger to complement a low frequency data service with a high frequency data provider unit, thus the combined device with the harness weighted approximately 60 grams, which was about 2.7% of the Eagle Owl's weight (2230 gram). The proportion was lower than the internationally accepted 3% rule. The VHF transmitter emitted a signal in every ten second and the estimated lifetime was four years. We deployed a full automatic receiver station in the guards' container in the mine yard that worked 24/7 and we recorded signal strength with a laptop. Data recorded by the automatic receiver station did not give information about the exact location of the bird, as it is not possible to detect direction of the transmitter with a single, fixed receiver. Signal strength however, indicated very accurately the presence/absence of the bird on the nesting cliff. According to previous tests, when the signal was strong, reaching the maximum value on the scale, we could be sure that the bird was on the cliff. As soon as the bird left the cliff, signal strength dropped significantly. There was not any radio signal emitting device in the area that could have distorted the signals of our VHF transmitter deployed on the bird. In addition to the automatic receiver station, VHF signals could be received also with a regular hand-held VHF receiver and a Yagi-antenna, thus Eagle Owl's roost sites during the day could be located. The VHF system including the transmitter and the receiver units and software was manufactured by Richard Wohlfart. Combining data received through the automatic receiver station and the hand-held receiver with the GPS-GSM data and visual observations (also with night-vision binoculars), we could make a good assessment of the bird's movements.

For technical reasons, we received comparable data between late February and early November, thus we evaluated data and present results from the period between 1 March and 31 October 2016.

GPS data showed the approximate range within the bird was moving during night that we put on a map (Minimum Convex Polygon) to visualize the home range of the Eagle Owl. The map was informative about the territory used by the bird, however information resulted from high-frequency VHF data were more important considering the aim of the study. We did not consider exact time of sunset and sunrise to keep processing simple. As a result, we received a very good visualization of owl's movements against circadian periods indicating the presence or absence of the bird on the nesting cliff. In addition, based on the quarry activity results, we showed (with a hypothetical value) every relevant human activity (disturbance) on the chart referring them to the date and time they happened. As a result, visual identification of disturbance events was straightforward.

All activities in the study was licensed by the environmental authority and requirements prescribed in the permit were strictly followed.

Results

We found that the Eagle Owl used intensively the nesting cliff throughout the year from the beginning of the year until early December, when she perished for unknown reason within the city limits of Kesztölc, the nearest settlement (the carcass was recovered with help of the tracking device). The female (and probably also the male) used the nesting cliff intensively especially during nights. The main resting area during daytime was not on the cliff, but over the top on the other side of the hill. The female perched on 15–20 metres tall, older trees covered with common ivy *(Hedera helix)*.

Although the pair did not start breeding, Eagle Owls' presence was gradually becoming more explicit towards May and June, spending more days on the cliff and being present every night. In July and August, the Eagle Owl avoided the cliff even in night, while in September, her presence was more explicit again, followed by a lower presence in October.

Circadian activities of owls usually followed the seasonally changing timing of sunset and sunrise. In many cases, the male and the tracked female (as visual observations confirmed) left the day roost and appeared on the cliff already at dusk. Usually the male arrived first and perched on his favourite rock or tree branch. The female usually showed up shortly after the male and she was less conspicuous, often we learnt about her approach only through the intensifying VHF signals. In some cases, she appeared much later than the male. In the night, she was away from the cliff mostly in the beginning or middle of the night period, when we suppose she was out hunting. In March, for example, she frequently left about two hours after sunset – around 8:00 pm CET – and returned only after midnight. However, we have records for earlier or later absence from the cliff and occasionally she left the cliff for hours twice a night. Oppositely, a few times she spent most of the night on the cliff. She always left the cliff only shortly before dawn every time, when she did not spend the daytime there. Vocalization was more intensive during the breeding period, but it occurred in every season.

We identified fifty days during the 245 days of the study period, when the tracked owl spent the entire daytime on the nesting cliff in the quarry. For forty nights the owl did not visit the cliff at all *(Figure 2)*. There were two occasions, when the owl spent the day in the quarry and the crusher was operating – the owl did not leave the cliff *(Figure 3)*. Human presence was continuous in the quarry, as the guards were always walking around regularly in the quarry in every hour according to their protocol.

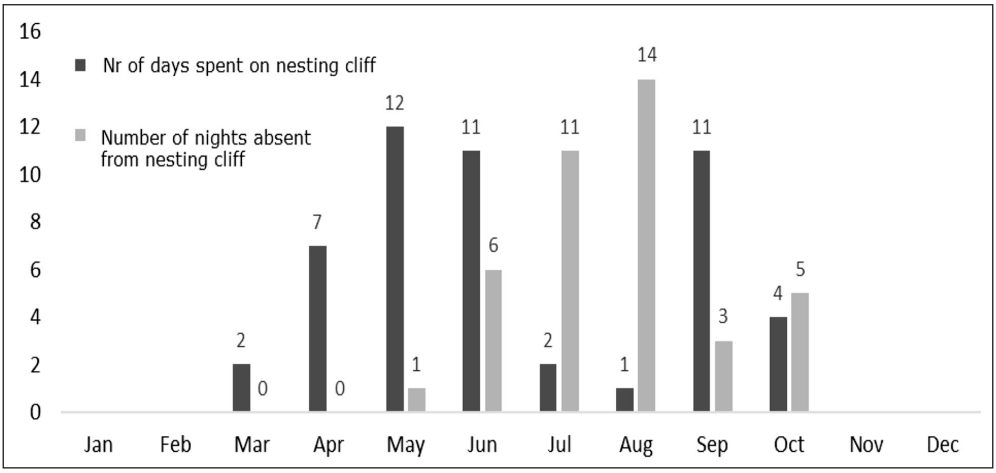

Figure 2. Number of days of diurnal presence and nocturnal absence on and from the nesting cliff
2. ábra A fészkelőfalon eltöltött nappalok és a faltól távol eltöltött éjszakák számának alakulása

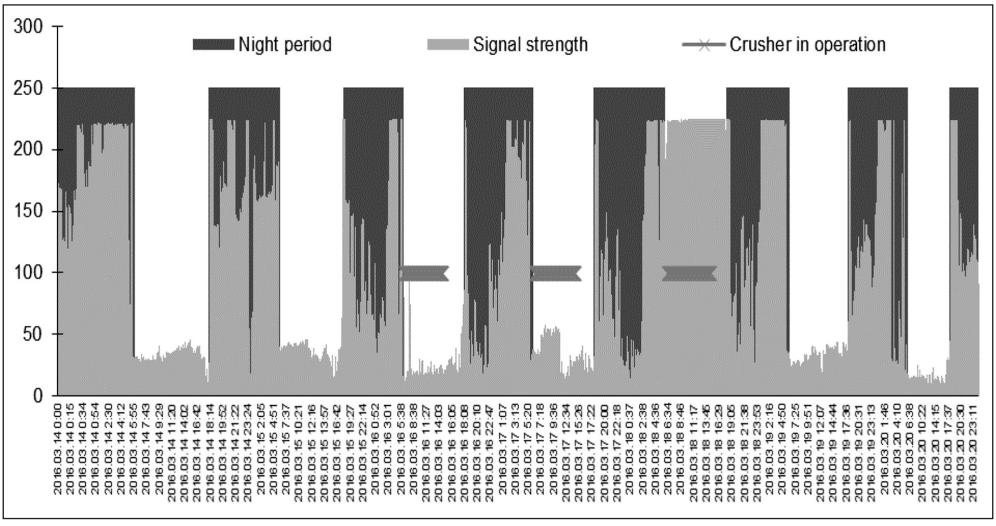

Figure 3. Diurnal and nocturnal presence of the tagged Eagle Owl on the nesting cliff in the period 14.03.2016 – 20.03.2016 indicated by VHF signal strength. On 18.03.2016 diurnal presence can be observed; the crusher was in operation on the same day
3. ábra A jeladós uhu nappali és éjszakai jelenlétének alakulása a fészkelőfalon 2016.03.14. és 2016.03.20. között, a VHF jelek erőssége alapján. Nappali jelenlét figyelhető meg 2016.03.18-án, amikor a törőgép üzemelt a bányaudvarban

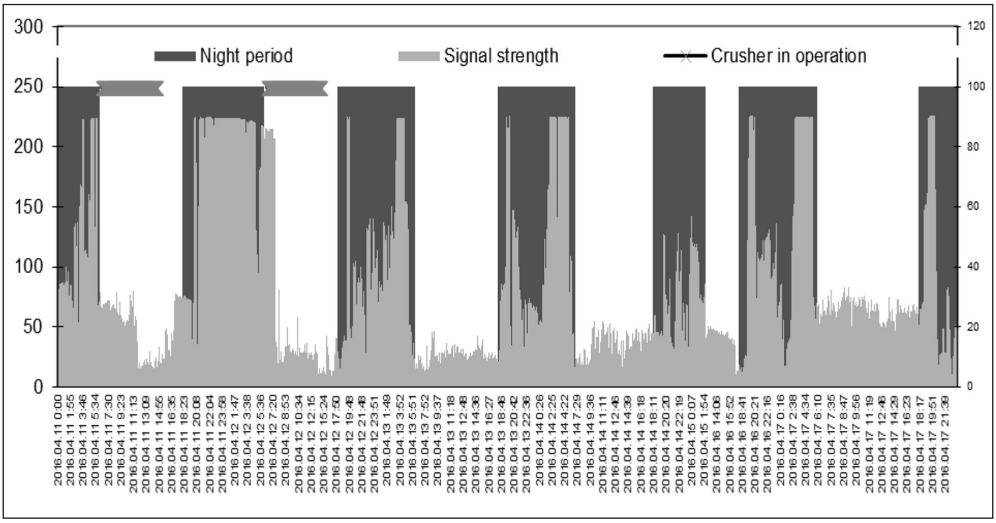

Figure 4. Diurnal and nocturnal presence of the tagged Eagle Owl on the nesting cliff in the period 11.04.2016 – 17.04.2016 indicated by VHF signal strength. The signal pattern indicates a disturbance event in the morning on 12.04.2016.

4. ábra. A jeladós uhu nappali és éjszakai jelenlétének alakulása a fészkelőfalon 2016.04.11. és 2016.04.17. között, a VHF jelek erőssége alapján. A jelek mintázata 2016.04.12-én zavarást jelez

When spending the daytime on the cliff, we found that she did not leave the roosting ledge during the day except for two cases (in April and June) that we identified as possible disturbance events *(Figure 4)*. According to the register book, on one of those days a heavy machine was doing earthwork on an upper terrace of the quarry close to the daytime roost of the owl.

Data from that device showed first the regular day roost area roughly 300 metres northeast from the cliff in straight line, where we found the Eagle Owl with the hand-held VHF receiver. The logger also confirmed our hypothesis that the adult female Eagle Owl remained within a few kilometres from the nesting site and regular roosting area. We found that the home range of the owl was about 18 km^2 including open and semi-open habitats with arable land bordered with patches of wood and abandoned vineyards. She visited two different manors of farmers' cooperatives, three and six kilometres from the cliff, to south and northwest, respectively *(Figure 5)*. The female Eagle Owl crossed linear infrastructures and even industrial zone on her revealed routes. It is likely that she flew over the village of Kesztölc regularly, as she hunted in its immediate vicinity. According GPS-GSM and VHF data, longer distance flights occurred in July and August, when she spent less time in the nesting cliff. The owl did not visit the closed forest areas in the mountains northeast of the cliff.

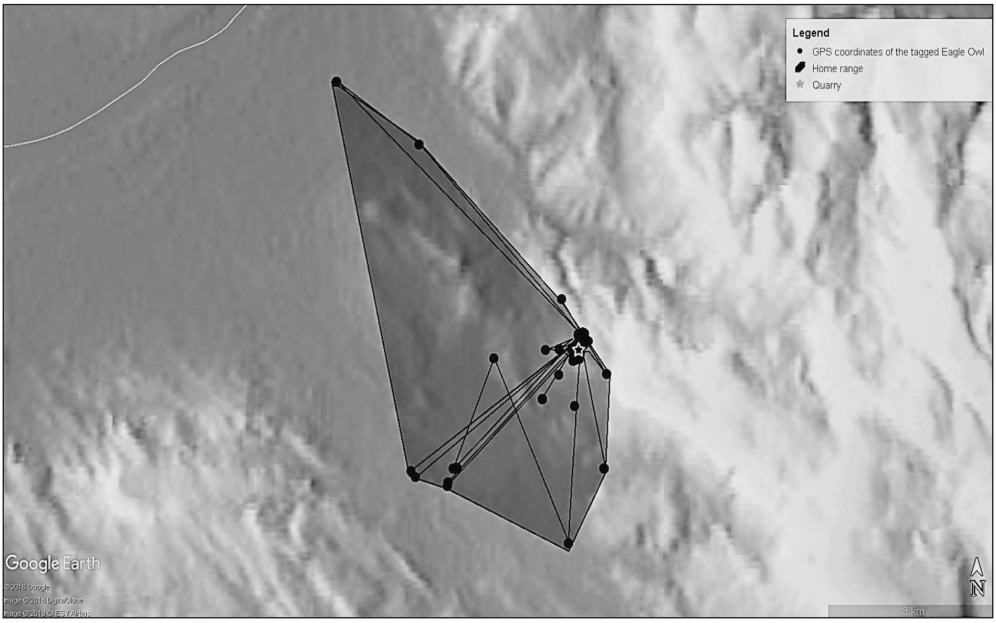

Figure 5. Area (minimum convex polygon) used by the tagged Eagle Owl based on GPS-GSM data
5. ábra A jelölt uhu által használt terület (minimum konvex poligon) a GPS-GSM adatok alapján

Discussion

The tracked female Eagle Owl spent considerable time – mostly at night, but also in daytime – on the cliff, even so that the pair did not breed in 2016.

Our study showed that the Eagle Owl tolerated repeated, non-targeted activities that occurred regularly and that was outside of a certain safety zone regardless if they were resulted from machines or men. Irregular operations, on an irregular place, closer than usual to the day roost of the owl however, can be classified as disturbance that may endanger breeding, if they often occur.

Studies focussed on owls' response to human disturbance (Delaney *et al.* 1999, Dalbeck & Breuer 2001) seem to be contradictory, but different types of disturbance must be evaluated separately. Regular "non-human" disturbance like quarry operations (Petrovics 2007), military helicopter practicing at low altitude (Delaney *et al.* 1999) has less impact on owls' behaviour, than seasonal direct human activities like rock climbing on the breeding cliff (Dalbeck & Breuer 2001). While owls can breed successfully in first case, in case of latter even breeding pairs can disappear, if the activity is not banned totally. Disturbance after all thus effects habitat quality. Quality of available habitats and individual choices has an impact on population density and breeding success (Penteriani *et al.* 2004). High tolerance of non-targeted disturbance had been reported from Germany, adding that Eagle Owls were even protected from targeted disturbance in actively used quarries (Harms 2015). The most important consideration is that no work or other human activity should be carried out in the

immediate vicinity of the breeding site (Lindner 2005). In East-Westphalia-Lippe, in Germany high percentage of breeding pairs were found in industrial areas including quarries (Lödige *et al.* 2008). Apparently, owls can get use to repeated, non-targeted, intense human disturbance (e.g. mechanical noise, traffic, mining activities etc.), while they are sensitive to targeted disturbance (e.g. rock climbing, dog walking, bird watching etc.) even if it happens on a significantly smaller scale compared to previous activities.

The avoidance of the cliff in the summer was not related to any human activity in the quarry. Apart from the fact that no nestlings bonded her to the cliff, one possible explanation is that in the summer period the cool forest roosts offer better microclimate than the sun-heated bare rock, which stores the heat also for the night. Additionally, also in other parts of the territory fully developed foliage provides good cover during the day. As an opportunistic predator, she hunted not only in natural and agricultural areas, but also very close to settlements and even in the immediate vicinity of buildings (manors). Other authors also found that Eagle Owls regularly spent daytime further away from the nesting cliff (Dalbeck *et al.* 1998).

In summary, the tracked Eagle Owl tolerated "business-as-usual" activities in the quarry, but she was sensitive to activities she had not been used to. This result is in accordance with the literature describing co-existence of Eagle Owl breeding and industrial activities in quarries. Findings suggest that full ban on mining activities in quarries, where Eagle Owls breed is not always necessary. Activities (e.g. explosion, opening new yards or terraces, doing occasional earthworks close to nest etc.) however, that go beyond normal operation in the breeding season must be carefully evaluated and restricted if they endanger breeding.

It is important to note that sensitivity to disturbance varies among individuals, as well as breeding season may shift within years depending on weather conditions, and there are differences also in geographical features of quarries. Thus, spatial-temporal restrictions of mining must be adjusted to the individual quarries and owls annually.

Our study did not detail possible schedules for restrictions, as the tracked female and her mate did not start breeding in 2016. Another weakness of the study is the limited number of tracked individuals. For that we plan to continue the research in the coming years to complete the study and have a broader base for conclusions.

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