Exploring the use of a carcass detection dog to assess mowing mortality in Hungary

Authors: Deák, Gábor, Katona, Krisztián, and Biró, Zsolt

Source: Journal of Vertebrate Biology, 69(3)

Published By: Institute of Vertebrate Biology, Czech Academy of Sciences

URL: https://doi.org/10.25225/jvb.20089

Journal of Vertebrate Biology

Open Access

J. Vertebr. Biol. 2020, 69(3): 20089

DOI: 10.25225/jvb.20089

SPECIAL ISSUE: DOGS AND CONSERVATION: CURRENT AND EMERGING CONSIDERATIONS

Exploring the use of a carcass detection dog to assess mowing mortality in Hungary

Gábor DEÁK[1*], Krisztián KATONA[2] and Zsolt BIRÓ[2]

[1] *MME Birdlife Hungary, Budapest, Hungary; e-mail: deak.gabor@mme.hu*

[2] *Szent István University, Institute for Natural Resources Conservation, Department of Wildlife Biology, Gödöllő, Hungary; e-mail: Katona.Krisztian@szie.hu, Biro.Zsolt@szie.hu*

Received 21 August 2020; Accepted 8 January 2021; Published online 27 January 2021

Abstract. The intensification of agriculture has resulted in changes to mowing techniques. Slow manual cutting gave wild animals time to move to safer habitat patches and left hiding places for them. With the arrival of much faster mowing machinery this is no longer the case. To date, there are few ways of measuring direct mortality of new mowing capabilities on wildlife. In our study we aimed to answer whether a search dog, previously trained to find carcasses, could be used to assess mowing mortality of various species in different vegetation types in Hungary. Working with a handler, a carcass-trained dog fitted with a GPS surveyed several habitats post-mowing. All the animal remains detected were identified and recorded. 149 killed individuals were detected on 12 land parcels studied (158.2 carcasses/100 ha). The most affected vertebrate group was the reptiles (57%), all with protected status in Hungary, followed by mammals (30%) and birds (6%). Reptiles were predominantly represented by lizards, while rodents were the most common mammals found (91% and 70%, respectively). The dog also found dead brown hares, pheasants and roe deer (11% of all carcasses), which has implications for local wildlife managers. There was no statistical difference in the density of dead individuals between grassy meadows and leguminous vegetation, or in those found in the morning or afternoon. The mortality rate was not associated with the area of the mowed field. Our findings suggest that this is a viable use of carcass detection dogs. We recommend additional work of this kind to reveal the fatal impacts of new, faster mowing practices on wildlife living in agricultural landscapes to help mitigate conservation and game management conflicts.

Key words: agricultural biodiversity, *Canis lupus familiaris*, European hare, pheasant, roe deer

Introduction

Meeting the increasing needs of human populations for food and other products from the world's crop and grasslands is a major global challenge (Pilling et al. 2020) that has led to agricultural intensification. Over the last half century, technological developments in agricultural production in Europe have fundamentally changed, including in Hungary where the number of tractors and harvesters per worker have steadily increased (Báldi & Faragó 2007). As a consequence, agricultural biodiversity has declined throughout Europe (Erisman et al. 2016), including bird, mammal, reptile and pollinator species. There has also been a severe decrease in the population abundance of small game species that occupy agricultural environments. This unfavourable trend appears to be associated with the transformation and elimination of former well-structured

* *Corresponding Author*

grassland habitats, large-scale cultivation and the introduction of intensive agricultural technologies (Edwards et al. 2000, Robinson & Sutherland 2002, Benton et al. 2003, Smith et al. 2005).

Traditionally, mowing on farms was accomplished through human and animal labour, and mowing larger areas (i.e. hundreds of hectares) could often take up to a month. Slow, step-by-step harvesting benefited wildlife because meadows developed a mosaic pattern, allowing individual animals to escape and different grass species to ripen (see e.g. Wan et al. 2016). However, the mechanization of agriculture has completely transformed and accelerated this traditional practice. Today, powerful and fast machines alter the structure and species composition of meadows, posing a serious threat to species occupying grasslands and hay fields.

In an 11-year study, Pépin & Angibault (2007) found that with the disappearance of vegetation patches (shrubs, alfalfa fields, fallow lands), hares were increasingly forced to occupy plough land and winter wheat fields. An agricultural landscape comprising less than 10% of such patches is sub-optimal for brown hares, increasing not only the likelihood of predation but also mortality related to intensive agricultural activities (mowing, harvesting, other agrotechnical work). Similarly, mowing increases the vulnerability of European hares (*Lepus europaeus*), who otherwise hide from aerial and terrestrial predators in high vegetation (Fernex et al. 2011). Schai-Braun (2013) showed the disruptive effect of agricultural machinery in Switzerland, as the home range of hares during their active period increased after the harvest. In Sweden, roe deer (*Capreolus capreolus*) fawn mortality caused by mowing was estimated at 25-44% of the yearly recruitment (Jarnemo 2002).

The extent of mowing mortality is hard to quantify both from a nature conservation and game management perspective. In most cases this impact is not monitored, but even if investigated, the small size of many carcasses and animal remains are hidden under mown vegetation. A simple visual observation by humans along transects may, therefore, be minimally effective (see e.g. Kis et al. 1998). However, dogs are able to find carcasses more effectively than human searchers (Homan et al. 2001, del Valle et al. 2020).

There are several initiatives in Europe to employ dogs in conservation work. In Spain, Italy and Hungary dogs are successfully used to detect illegally poisoned raptors (Simón et al. 2007, Deák et al. 2020). Search dogs were also used to detect dead remains of birds and bats (Paula et al. 2011), threatened (Nussear et al. 2008) or aggressively invasive species (Vice & Engeman 2000), living (Cablk & Heaton 2006, Dahlrgen et al. 2010) or dead animals (Deák & Horváth 2018).

Our study examined whether detection dogs trained to find carcasses and poisons could also be effectively used to reveal mowing mortality. Our questions were: 1) How many species/individual carcasses could be detected by dogs after mowing in different agricultural crops? 2) Is there any difference in mowing mortality due to vegetation type or mown area? 3) Are there any difference in the number of carcasses revealed by morning (immediately after mowing) or afternoon searches using a dog?

Material and Methods

Study area

The effect of agricultural mowing machines was investigated in Jászság, Hungary (Fig. 1). The area is neither under legal conservation protection or part of the NATURA 2000 network. This landscape contains large cultivated fields of alfalfa or other leguminous crops, maize, winter wheat, rape and sunflower, grass meadows and some small forest blocks and shrubby patches. Tree and shrub alleys line agricultural parcels, but mainly it is grass strips that delineate the edges of fields.

In May and June 2018, we surveyed a total area of 94.2 ha, containing 49.6 ha of leguminous vegetation and 44.6 ha of grass meadows, and with parcel sizes ranging from 2.2 to 20 ha. We obtained six observations on mowing mortality for both vegetation types (see in Table S2).

Mowing was performed with a John Deere 6930 tractor with DISCO 3100 FRC front disc mower and DISCO 3100 TRC trailed disc mower. The mower consisted of seven discs and was 3 m wide. The cutting height was set at 8 cm in alfalfa and other leguminous fodder and at 5 cm in natural grasslands. The mowers were equipped with a stalk chopper that destroys the stem and leaf portions of the cut hay fodder, thereby opening surfaces for faster moisture release to hasten drying. All mowing was done during the day and only one machine at a time was working, except on one occasion.

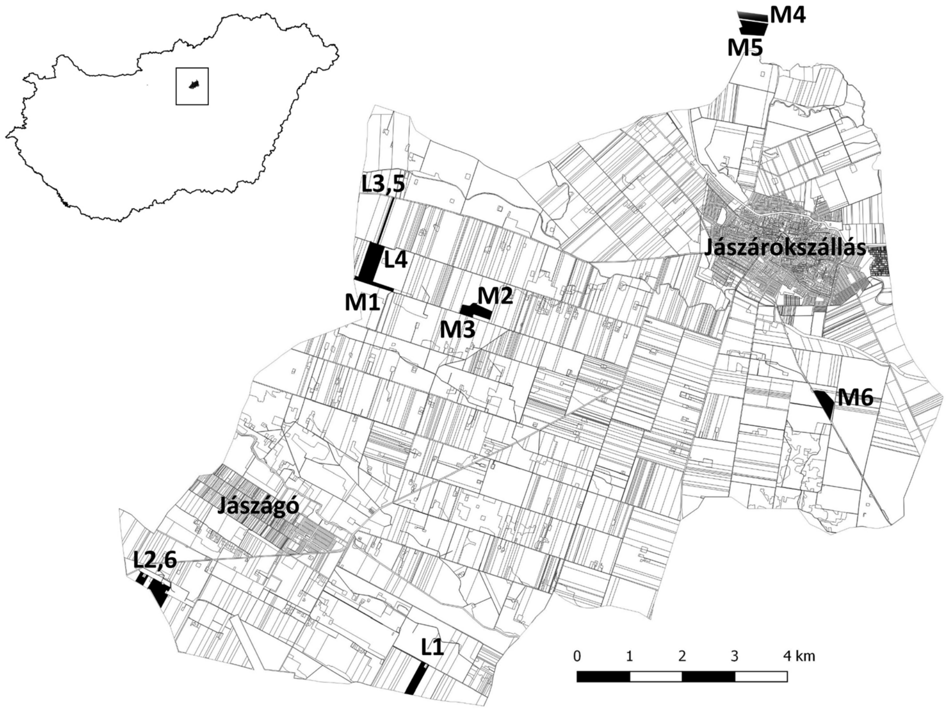

Fig. 1. Map of the study area in Jászság, Hungary showing the positions of the studied parcels of land (M1-6: mowed parcels of grass meadows, L1-6: mowed parcels of leguminous vegetation).

Local wildlife populations

The most common game species in our study area potentially affected by mowing were roe deer, European hare and pheasant (*Phasianus colchicus*). Their estimated population density by hunters in 2018 was five, twelve and six individuals per 100 ha, respectively. Additionally, we observed different protected ground nesting birds (e.g. lapwing *Vanellus vanellus* or Eurasian skylark *Alauda arvensis,* common quail *Coturnix coturnix*), reptiles (e.g. sand lizard *Lacerta agilis*, European pond turtle *Emys orbicularis,* grass snake *Natrix natrix*), amphibians (e.g. green toad *Bufo viridis*, common spadefoot toad *Pelobates fuscus*, European tree frog *Hyla arborea*, fire-bellied toad *Bombina bombina*) and small mammals (mainly voles and mice, e.g. *Microtus arvalis, Apodemus agrarius*). Non-vertebrate taxa potentially impacted by mowing in these areas included gastropods (e.g. Roman snail *Helix pomatia*) and insects (mainly Orthoptera, e.g. European mantis *Mantis religiosa*).

Mowed landscape surveys with a trained carcass detection dog

In our study we used a six-year-old, male German shepherd dog named Falco. Falco is the first carcass and poison searching dog for nature conservation purpose in Hungary, which was initiated in the autumn of 2013 within the framework of the project "HELICON – Protection of the imperial eagle in Hungary" LIFE10NAT/HU/019. The dog is certified by the National Police Headquarters (NPH), Police Education and Training Centre as an official carcass and poison search dog. The first author of this paper (G. Deák) is Falco's sole owner/handler and has a poison and carcass-seeking dog guide license, also issued by NPH.

Falco received four-month intensive carcass search training, using several species of birds; e.g. *Buteo* and *Corvus* sp. and mammals, e.g. European hares or *Vulpes vulpes*, in different stages of decomposition. The dog was also trained to carbofuran and phorate; the two most commonly identified pesticides from poisoned bird species in Hungary. Because of his role as a poison detection dog, the reward for Falco was always a toy, never food, since even a small amount of a poisoned bait could be lethal, and any link between a find, the reward and food was avoided.

Although in principle Falco was trained for finding decomposed carcasses, rather than freshly killed animals, there would be common scent characteristics, and the dog was able to learn to recognize a spectrum of carcass freshness over more than 5-years of field work. Over seven years of active duty until 2020, Falco found and indicated 392 carcasses in various stages of decomposition (later determined to have been poisoned). Additionally, Falco found a large number of non-poisoned carcasses of different species during anti-poisoning surveys. Falco also has prior experience of conservation detection work (gray wolf *Canis lupus* scat searches for the Sustainable Nature Conservation in Natura 2000 Areas in Hungary (SH/4/8)), and searching for occupied dens of steppe polecat *Mustela eversmanni* (Nature Conservation Compensation Scheme 2015 (TMF/667/8/2015)).

A younger dog (named Carlo, see poison detection paper by Deák et al. 2020) was considered for this work and trained to a certain extent, but was ultimately not used and is not discussed further.

Falco worked freely in each field, i.e. unleashed, moving and searching within about 50 m strips between 10 and 30 meters in each direction from the handler (G. Deák), covering whole parcels of land. A canine GPS-collar system (T5 dog device and Garmin Astro 320 handheld) was used to record the route of the dog and the handler as well as the location of carcasses (Fig. S1).

The mowing work began in the study area between 8 and 9 am, after the dew had dried. Searches were conducted as soon after mowing as possible to avoid removal of carcasses by mammalian and avian scavengers attracted to the mown fields by feeding opportunities. This also ensured the dog was kept well away from the mowing machines. One searching session lasted 47.28 ± 16.8 minutes. High temperatures at midday were avoided and a second searching session was performed in the afternoon.

When finding an animal remnants the dog actively signed to its handler by barking. The observed detection distance (where the dog appeared to first perceive the odour before working towards the carcass) was between 0 and 200 m, depending on wind speed and direction. The search direction was selected along transects perpendicular to the wind direction (if starting with a headwind, it is less favourable to search in the tailwind after a turn). In the case of perpendicular wind the possibility increases that the dog perceives and re-signals a carcass found along the previous transect, but during training and active work, Falco learned there would be no reward for repeatedly indicating the same carcass. After finding a carcass, searching was resumed 3 m away.

After photographing the dog's find and recording the species, all carcasses (intact or otherwise) were left in place to provide food for scavengers, including some protected birds, such as the Eastern imperial eagle (*Aquila heliaca)*, common buzzard (*Buteo buteo*), Eurasian marsh-harrier (*Circus aeruginosus*) and white stork (*Ciconia ciconia*). If the dog found remnants of a carcass, we recorded it as the lowest certain number of individuals.

Data analysis

The density of the various species groups and that of all carcasses in the different vegetation types were compared with Mann-Whitney U-test after performing Shapiro-Wilk normality test. The effect of the dog-handler search timing (morning or afternoon work) on the findings was investigated with independent samples t-test. A negative binomial GLM was used to examine the relationship between the size of the searched fields and the number of carcasses/remains found. All statistical analyses were done with SPSS version 20 (IBM Corp.).

Results

Falco searched the fields with an average speed of 4.38 ± 0.71 km/h and the km index of the found carcasses was 2.74 ± 1.68 remains/km. The dog found 11.51 ± 6.78 carcasses/h on average.

We detected 149 killed individuals (Table S1) across 12 surveyed parcel of land representing 158.2 carcasses/100 ha (Table S2). Reptiles, which are all protected in Hungary, were the most affected vertebrate group (57%). Reptiles were mainly represented by sand lizards (91%), though some grass snakes were also observed. Mammals and birds comprised 30% and 6% of carcasses, respectively.

The dog also found brown hares, pheasants (Fig. S2) and roe deer (11% of all carcasses), indicating damage for local game managers. In the case of legumes and grassland, four dead European hares were found to have died as a result of mowing in each crop type. Several rodents (the second most frequent group, 21% of total remnants and 70% of mammals), some small passerines (2.7% of total remnants) and quails (1.3% of total remnants) were also detected by the dog. A detailed list of the species that were killed to mowing, and their proportions, can be found in Table S1.

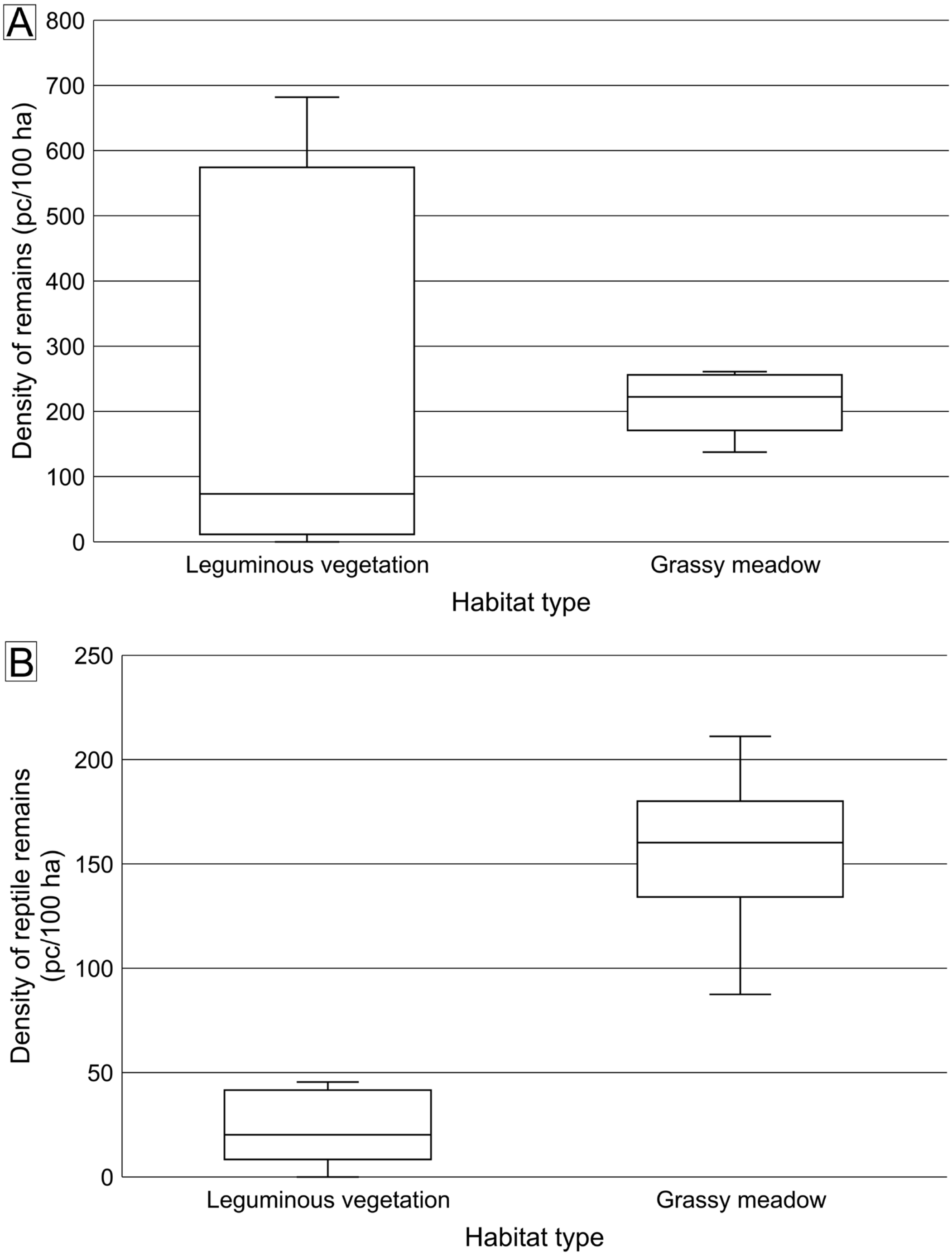

Fig. 2. A) Difference between leguminous vegetation and grass meadow in the density of animal remains found. B) Difference between leguminous vegetation and grass meadow in the density of reptile remains found.

No significant difference was observed in the density of animals (Table S2) killed by mowing, either in legume crops (median mortality = 73.55 remains/100 ha) or grassland (median mortality = 222.22 remains/100 ha; Mann-Whitney U-test: U = 24, $n_{1,2}$ = 6, *P* = 0.394; Fig. 2A). Both, the smaller- (skylarks, rodents, lizards, snakes) and larger-bodied (quails, pheasants, hares, roe deer) categories showed no significant difference between the two habitat types (Mann-Whitney U-test: U = 12, $n_{1,2}$ = 6, *P* = 0.394, U = 20, $n_{1,2}$ = 6, *P* = 0.818, respectively). However, if we separated the carcasses among reptiles, birds and mammals, more reptile remains were found on grassy meadows than on leguminous fields (Mann-Whitney U-test: U = 5, $n_{1,2}$ = 6, *P* = 0.041; Fig. 2B). The other animal groups showed no significant differences (Mann-Whitney U-test: U = 22, $n_{1,2}$ = 6, *P* = 0.589 for birds and U = 19.5, $n_{1,2}$ = 6, *P* = 0.818 for mammals).

Considering search times, there was no significant difference between searches immediately after mowing in the morning (mean ± SD = 134.45 ± 106.17) and later in the afternoon (mean ± SD = 309.21 ± 249.85; independent samples t-test with equal variances: t = –1.577, df = 10, *P* = 0.146).

The size of the mown area did not appear to affect the number of animals killed (negative binomial GLM: the effect of the area size on the carcass density was –0.087, Chi^2 = 3.195, df = 1, *P* = 0.074).

Discussion

We found that using a dog trained to find carcasses as part of anti-poisoning surveys can also be valuable in finding the remains of animals that have died as a result of mowing. Matthews et al. (2013) and del Valle et al. (2020) also demonstrated that dogs that received prior training were much more effective than human observers in finding dead bats and birds.

Our results show that mowing leguminous vegetation or grassland poses a threat to a variety of vertebrate species. The finds made during the dog-handler surveys confirm, and previous studies have shown, that grassy meadows and legume cultivation offer foraging, hiding and nesting sites for several animal species during spring and summer, resulting in disturbances by agricultural works and leading to significant mowing mortality when these crops are harvested (e.g. Tyler et al. 1998, Viszló 2012, Vadász & Lóránt 2014, Faria et al. 2016).

Visual searches for small animals, like lizards, whose remains can be hidden under the cut vegetation, are extremely challenging. Moreover, some organisms can be obliterated during mowing, which occurs when smaller animals cling to the vegetation and are drawn into the stalk-breaking equipment, which entirely crushes them. This may explain why the remains of arthropods and amphibians were not found during searches. For example, Humbert et al. (2010a) observed that meadow harvesting caused the direct mortality of 65-85% orthopterans (21-57% mortality caused by mowing), which suggests there may be a high impact on invertebrates. In the case of amphibians another explanation for the lack of carcasses, particularly toads, was that surveys were conducted during a dry period. Toads may have been dormant, hidden in cracks of the soil, and thus protected from the disc-mower.

In principle, reptiles would be expected to be mobile at ground level rather than on the surface of vegetation. As a result, the killed animals were not totally obliterated by the mower. Durbian (2006) reported high mortality of the massasauga (*Sistrurus catenatus*), a snake species in Missouri, caused by mowing, as a result of crushing by tractor tyres, contact with the mower blades, or indirectly through depredation in the freshly mown area.

Comparison of vegetation types showed that 84% of reptile remains were found on natural grassland. This habitat offers more varied micro-topography and diverse vegetation patches and tends to promote taxonomic diversity. The greater diversity of the grassy meadows might, therefore, result in more carcasses in that habitat type. However, the difference was not significant, though with a larger sample of each habitat type this difference may be supported. Reptiles occurred in grassland meadows in greater numbers than arable crops. Notably, the cutting height of the mower was set at 5 cm on grassland, lower than when mowing leguminous crops, in order to produce larger amounts of fodder. For this reason farmers do not want to raise the blades, even if it would result in lower mortality. Additionally, farmers do not utilize a chain curtain (Fig. S3), which alerts wildlife to the mower so that they can escape, because they do not perceive it is effective in decreasing wildlife mortality. A lower cutting height and failure to use a chain curtain probably contribute to a greater number of mortalities of small-sized species.

One of the main challenges of the study in relation to using dogs was the difficulty of planning the exact time and place of searches due to unpredictable weather and changes in the work schedule and priorities of farmers. These uncertainties meant that it was impossible to search fields for carcasses prior to mowing. It was important that searches are made immediately after mowing, because scavenging animals will constantly visit the area for the expected food during and after agricultural work. Scavenging species can rapidly remove a significant number of small animal remains without any trace (Balcomb 1986). For this reason we predicted that we would detect more carcasses in the morning than in the afternoon. In fact we found the reverse, perhaps due to the increased concentration of volatiles associated with longer decomposition. Although the work of the search dog was sometimes hampered by high temperatures (if the dog is panting, it is harder to sniff), we did not notice any difference in the temporal distribution of detections during searches.

Conclusions and recommendations

Our study provides a case study for dogs to be trained and used effectively to assess mowing mortality in wildlife. Assessing the exact damage caused by mowing is a complex task. Ideally, surveys of living fauna before and after mowing should be conducted, using dogs or other complimentary techniques (e.g. strip census or netting), so that a baseline is obtained for comparison with mortalities associated specifically with mowing thereby enabling estimation of the influence of mowing mortality on population dynamics.

Because the work was, of necessity, conducted in warm weather, it could also be beneficial to work with two dogs, in shifts. Poison/carcass-seeking dogs are taught to use active signalling (i.e. barking), because the search is often carried out in dense vegetation and bushes. However, for inspecting mown arable fields, the dog works in an open area within continuous view of the handler. Therefore, passively alerting (i.e. either a sit or down position) to signal carcass detection will be less exerting for the dog. Although for poison detection work Falco was trained solely with decomposed carcasses, the dog was able to find fresh remains. For a nature conservation application, we recommend training dogs on a combination of fresh and decomposed carcasses. The training of the dog and the handler contributes to the success of the search. The handler must guide and support the dog, and the dog must perform a focused search on an area to find each carcass. For this task an inexperienced person using a pet dog will have limited success. Using a dog across projects, to achieve multiple conservation purposes and benefits, makes even more effective use of the resources invested in their training. Comparative studies on the effectiveness of searching between different trained dogs and between human surveyors and dog-handler groups would be valuable to refine the method.

In order to introduce appropriate conservation measures to reduce mowing mortality, it is necessary to examine the impact of mowing in different periods of the day or year (e.g. Broyer et al. 2020) and using different harvesting equipment (e.g. Humbert et al. 2010b). Leguminous crops and, in high-rainfall years, natural grassland may be mown several times in a given year, which can also affect the results. These activities are of special importance on the self-managed grasslands of the National Parks, which support particularly abundant wildlife.

In addition to technological factors, the attitudes of farmers also plays an important role in limiting damage to wildlife. It was notable that farmers do not consider the chain curtain on mowers to be effective in protecting wildlife and, since there is no unequivocal legal obligation for its use in these areas, they rarely utilise it. It would also be valuable if farmers notified conservation and hunting associations in advance of mowing to enable them to survey wildlife (e.g. using aerial thermography, Cukor et al. 2019), or potentially to enable some species to be driven away, removed or protected locally (e.g. by enclosing or marking a nest). A well-functioning wildlife alert system, with monitoring and rescue interventions acceptable by all partners, will be essential to decrease this kind of avoidable, non-targeted impact on agricultural biodiversity.

Acknowledgements

The research was funded by the Ministry of Agriculture (EVGF/827/2017) and the PannonEagle Life project (LIFE15/NAT/HU/000902). We are grateful to local farmers (especially to Kossuth 2006 Mezőgazdasági Termelő JSC) and game managers (mainly to János Fehér) for their cooperation in conducting our research, and János Maticsek (chief warrant officer, police counsellor at Service Dog Training Centre of the Hungarian Police, Dunakeszi) for help with dog training. There were no ethical implications arising in the study. Author contributions: G. Deák – owner and handler of the dog, performing searches after mowing, writing the manuscript; K. Katona – analysing data, writing the manuscript; Z. Biró – planning the investigation, analysing data, writing the manuscript.

Literature

Balcomb R. 1986: Songbird carcasses disappear rapidly from agricultural fields. *Auk 103: 817–820.*

Báldi A. & Faragó S. 2007: Long-term changes of farmland game populations in a post-socialist country (Hungary). *Agric. Ecosyst. Environ. 118: 307–311.*

Benton T.G., Vickery J.A. & Wilson J.D. 2003: Farmland biodiversity: is habitat heterogeneity the key? *Trends Ecol. Evol. 18: 182–188.*

Broyer J., Belghali S., Le Goff C. et al. 2020: Spatial convergence of meadow passerine territory distribution with mowing delay: an experiment in lowland grasslands. *J. Ornithol. 161: 769–778.*

Cablk M.E. & Heaton J.S. 2006: Accuracy and reliability of dogs in surveying for desert tortoise. *Ecol. Appl. 16: 1926–1935.*

Cukor J., Bartoška J., Rohla J. et al. 2019: Use of aerial thermography to reduce mortality of roe deer fawns before harvest. *PeerJ 7: e6923. http://doi.org/10.7717/peerj.6923.*

Dahlrgen D.K., Messmer T.A., Thacker E.T. & Guttery M.R. 2010: Evaluation of brood detection techniques: recommendations for estimating greater sage-grouse productivity. *West. N. Am. Nat. 70: 233–237.*

Deák G., Árvay M. & Horváth M. 2020: Using detection dogs to reveal illegal pesticide poisoning of raptors in Hungary. *J. Vertebr. Biol. 69: 20110. https://doi.org/10.25225/jvb.20110.*

Deák G. & Horváth M. 2018: 2016 report of the poisoning prevention working group. *Heliaca 14: 68–73. (in Hungarian)*

del Valle J.D., Peralta F.C. & Arjona M.I.J. 2020: Factors affecting carcass detection at wind farms using dogs and human searchers. *J. Appl. Ecol. 57: 1926–1935.*

Durbian F.E. 2006: Effects of mowing and summer burning on the massasauga (*Sistrurus catenatus*). *Am. Midl. Nat. 155: 329–334.*

Edwards P.J., Fletcher M.R. & Berny P. 2000: Review of the factors affecting the decline of the European brown hare, *Lepus europaeus* (Pallas, 1778) and the use of wildlife incident data to evaluate the significance of paraquat. *Agric. Ecosyst. Environ. 79: 95–103.*

Erisman J.W., Van Eekeren N., Koopmans C. et al. 2016: Agriculture and biodiversity: a better balance benefits both. *AIMS Agric. Food 1: 157–174.*

Faria N., Morales M.B. & Rabaça J.E. 2016: Exploring nest destruction and bird mortality in mown Mediterranean dry grasslands: an increasing threat to grassland bird conservation. *Eur. J. Wildl. Res. 62: 663–671.*

Fernex A., Nagel P. & Weber D. 2011: Sites with reduced predation risk to young hares within an agricultural landscape. *Mammalia 75: 395–397.*

Homan H.J., Linz G.M. & Peer B.D. 2001: Dogs increase recovery of passerine carcasses in dense vegetation. *Wildl. Soc. Bull. 29: 292–296.*

Humbert J.-Y., Ghazoul J., Richner N. & Walter T. 2010a: Hay harvesting causes high orthopteran mortality. *Agric. Ecosyst. Environ. 139: 522–527.*

Humbert J.-Y., Ghazoul J., Sauter G.J. & Walter T. 2010b: Impact of different meadow mowing techniques on field invertebrates. *J. Appl. Entomol. 134: 592–599.*

Jarnemo A. 2002: Roe deer *Capreolus capreolus* fawns and mowing – mortality rates and countermeasures. *Wildl. Biol. 8: 211–218.*

Kis J., Váczi O., Katona K. & Altbäcker V. 1998: The effect of vegetation height on the density of European ground squirrels (*Spermophilus citellus*) in a Hungarian reintroduced population. *Termvéd. Közl. 7: 117–123. (in Hungarian)*

Matthews F., Swindells M., Goodhead R. et al. 2013: Effectiveness of search dogs compared with human observers in locating bat carcasses at wind-turbine sites: a blinded randomized trial. *Wildl. Soc. Bull. 37: 34–40.*

Nussear K.E., Esque T.C., Heaton J.S. et al. 2008: Are wildlife detector dogs or people better at finding desert tortoises (*Gopherus agassizii*)? *Herpetol. Conserv. Biol. 3: 103–115.*

Paula J., Leal M.C., Silva M.J. et al. 2011: Dogs as a tool to improve bird-strike mortality estimates at wind farms. *J. Nat. Conserv. 19: 202–208.*

Pépin D. & Angibault J.M. 2007: Selection of resting sites by the European hare as related to habitat characteristics during agricultural changes. *Eur. J. Wildl. Res. 53: 183–189.*

Pilling D., Bélanger J. & Hoffmann I. 2020: Declining biodiversity for food and agriculture needs urgent global action. *Nat. Food 1: 144–147.*

Robinson R.A. & Sutherland W.J. 2002: Post-war changes in arable farming and biodiversity in Great Britain. *J. Appl. Ecol. 39: 157–176.*

Schai-Braun S.C. 2013: Daily activity pattern, space use and habitat preferences of the European hare (*Lepus europaeus*). *PhD Thesis, University of Natural Resources and Life Sciences, Vienna.*

Simón M.A., Couto S., Carrasco A.L. et al. 2007: The reintroduction of the bearded vulture *Gypaetus barbatus* in Andalusia, southern Spain. *Vulture News 56: 29–40.*

Smith R.K., Jennings N.V. & Harris S. 2005: A quantitative analysis of the abundance and demography of European hares *Lepus europaeus* in relation to habitat type, intensity of agriculture and climate. *Mammal Rev. 35: 1–24.*

Tyler G.A., Green R.E. & Casey C. 1998: Survival and behaviour of corncrake *Crex crex* chicks during the mowing of agricultural grassland. *Bird Study 45: 35–50.*

Vadász C. & Lóránt M. 2014: Key mortality causes of the great bustard (*Otis tarda*) in Central Hungary: an analysis of known fatalities. *Ornis Hungarica 22: 32–41.*

Vice D.S. & Engeman R.M. 2000: Brown tree snake discoveries during detector dog inspections following super typhoon Paka. *Micronesica 33: 105–110.*

Viszló L. 2012: Nature-friendly grassland management: traditional approach, modern tools. *Pro Vértes Public Foundation for Nature Conservation, Csákvár. (in Hungarian)*

Wan Z., Yang J., Gu R. et al. 2016: Influence of different mowing systems on community characteristics and the compensatory growth of important species of the *Stipa grandis* steppe in Inner Mongolia. *Sustainability 8: 1121.*

Supplementary online material

Fig. S1. A sample map showing the dog and dog handler tracks and the locations of detected carcasses in a land parcel.

Fig. S2. Falco detecting a dead pheasant hen and destroyed nest under mowed vegetation.

Fig. S3. Chain curtain in use (attached between the tractor and the blades).

Table S1. Distribution of species in the total number of detected carcasses in two different habitat types, in Hungary (May-June, 2018). *In the case of pheasant and quail one record in leguminous vegetation relates to the destruction of an entire clutch of each species.

Table S2. Observed parameters during searches with a carcass detection dog after mowing in different vegetation types, Hungary (May-June, 2018). Morning and afternoon searches were carried out for the same duration from 9:21 to 13:31 and 16:25 to 20:10, respectively.

(https://www.ivb.cz/wp-content/uploads/JVB-vol.-69-3-2020-DeakG.-et-al.-Figs.-S1-S3-Tables-S1-S2.docx)