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Source: Ardea, 95(2) : 267-274

Published By: Netherlands Ornithologists' Union

URL: https://doi.org/10.5253/078.095.0209

Can noxious odours effectively protect clutches of ground-nesting birds?

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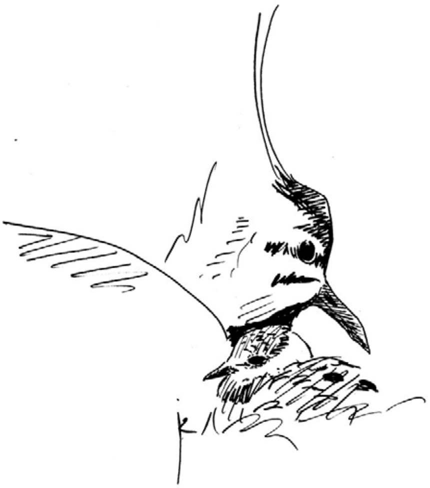

Düttmann H., Lettau K. & Barkow A. 2007. Can noxious odours effectively protect clutches of ground-nesting birds? Ardea 95(2): 267–274.

In search for an alternative to lethal methods of predator control, we tested the efficacy of two noxious odours, Hukinol and Hundeschreck, as predator repellents in field experiments with artificial and real nests. Hukinol produces a strong human scent, whereas Hundeschreck is a combination of minerals, plant extracts, and pelargonic acid. In two field experiments with artificial nests exposed in open landscapes of Western Lower Saxony, we found no evidence for a longer survival rate of nests treated with the odour repellents. The same result was obtained in a pilot study with real nests of Lapwing *Vanellus vanellus*. In the latter study half of the nests were treated with Hukinol, the others were used as controls. In summary, both chemicals show little promise in reducing predation-dependent nest failure in ground-nesting birds.

Key words: predator control, odour repellents, artificial nests, Lapwing

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INTRODUCTION

In Central Europe most meadowbird species declined in breeding numbers during the last decades (Bauer & Berthold 1997, Krebs *et al.* 1999, Donald *et al.* 2001, Nehls *et al.* 2001, Teunissen 2004, Wilson *et al.* 2004). The factors driving these population changes are not yet well understood. However, for several grassland-breeding waders there are strong indications for changes in productivity (Grant *et al.* 1999, Schekkerman & Müskens 2000, Chamberlain & Crick 2003). One potential factor for an insufficient reproductive success is an increasing influence of predators which consume eggs, chicks or adult birds. Indeed, several mammalian and avian predators of meadowbirds have increased during the period of population declines (compare Bauer & Berthold 1997, Baillie *et al.* 2002, Bellebaum 2003). In line with this, some studies found evidence that predation has become a serious problem in meadowbird areas in recent years (Grant *et al.* 1999, Brandsma 2002, Chamberlain & Crick 2003, see also review of Langgemach & Bellebaum 2005). Investigations aimed to identify nest predators of grassland-breeding waders revealed carnivorous mammals as the most important species, especially in areas with a high daily predation risk (Bellebaum 2002, Blühdorn 2004, Teunissen *et al.* 2005a).

A variety of killing methods has traditionally been employed to control predators (Tapper 1992, Reynolds 2000). However, reviews of predator control experiments found no general positive effect on nest success, fledging rate, or breeding numbers of target bird species (see Côte & Sutherland 1997). Moreover, control of predators by lethal means is not always appropriate or practical, e.g. in nature reserves.

With regard to non-lethal alternatives a variety of measures have been tested with variable success. Fencing, for instance, is one way to reduce predation on ground-nesting birds (Minsky 1980, Cowardin *et al.* 1998, Aguon *et al.* 2002). However, the installation of electrical or conventional fences might also hamper the movements of non-target species. Moreover, fencing often requires a lot of manpower, which makes it expensive. Further non-lethal options discussed for predator control are conditioned taste aversion, fertility control and the use of repellents. Most of these techniques are still under scientific investigation and in the case of fertility control also need ethical discussions before they can be applied in the field (Tuyttens & Macdonald 1998, Baker & Macdonald 1999, Cowan *et al.* 2000).

In the present study we investigated the efficacy of two noxious odours as repellents for the protection of clutches of ground-nesting birds. Repellency works via the repetitive application of a noxious stimulus that is avoided by the recipient. In previous studies olfactory chemicals were effectively used to prevent specific plants from herbivory for at least a limited period of time (Rosell & Czech 2000, Rosell 2001, but see also Andelt *et al.* 1991). With regard to olfactory chemicals that have an aversive effect on predators results are scarce and restricted to just a few species. Lehner and coworkers (1976), for instance, tested 45 candidate substances on Dogs *Canis familaris* and Coyotes *Canis latrans* with inconclusive or negative results. In contrast, Landa & Tømmerås (1997) had success with several taste and olfactory chemicals that elicited aversive reactions in Wolverines *Gulo gulo* in laboratory experiments. However, earlier investigations demonstrated that promising laboratory results were not transferable into the field (Landa *et al.* 1996).

In our study we tested the repellent effects of two noxious odours called Hukinol and Hundeschreck in multipredator ecosystems. Hukinol is a fluid substance which imitates strong human scent (Kieferle GmbH, Gottmadingen). In Germany it is used by farmers and hunters to prevent game damage. In contrast, the granular substance Hundeschreck is originally designed to induce a change in the home range of dogs. It consists of minerals, plant extracts and pelargonic acid (Neudorff GmbH, Emmerthal). Since both agents seem to possess repellent characteristics for carnivorous mammals, we investigated their usability for the protection of nests of ground-breeding birds. In a first step we used both substances for the protection of artificial nests in open landscapes. Since several comparative studies demonstrated that real and artificial nests are not depredated at the same rate (Valkama *et al.* 1999, Davison & Bollinger 2000, Thompson III & Burhans 2004), we additionally tested the efficacy of Hukinol in a pilot study at real nests of the Lapwing.

METHODS

Study sites

The artificial nest experiments were carried out in the semi-open grassland reserve Kuhdammoor-Melmmoor and an adjacent industrial peat cutting field near Esterwegen (Lower Saxony, Germany). Differences in the survival of Lapwing nests treated with Hukinol and untreated controls were investigated in three grassland reserves (Vreeser Wiesen, Leher Wiesen, and Kuhdammoor-Melmmoor) located in Western Lower Saxony. In all these reserves contracts with local farmers prevented the nests of meadowbirds from destruction by agricultural activities, notably by cattle and machines.

Unpublished bag records and monitoring data revealed the presence of several carnivorous mammals and avian predators, e.g. Red Fox *Vulpes vulpes*, Polecat *Mustela putorius*, Stoat *Mustela* *erminea*, Weasel *Mustela nivalis*, Carrion Crow *Corvus c. corone*, and Buzzard *Buteo buteo* in all study sites. Moreover, Kiffmeyer (2002) showed that predation caused high nest losses in the ground-breeding Golden Plover *Pluvialis apricaria* in the study sites near Esterwegen.

Artificial nest experiments

In early March 2003 we used 34 artificial nests to test the efficacy of Hukinol as predator repellent. Each nest contained three eggs of Quail *Coturnix coturnix*, which we obtained from a professional breeder. The nests were randomly exposed in open grasslands of the nature reserve Kuhdammoor-Melmmoor. For later control we marked all nests with small bamboo sticks of 1 m height. Two of these sticks were exposed in 3 m distance, the nest in between. Earlier investigations found no evidence that this way of marking attract the special attention of predators (Beintema & Müskens 1987). Half of the nests (n = 17) were treated with Hukinol by laying the fluid substance on the neighbouring sticks. The other nests were used as controls. We checked the survival of the nests by regular visits at 1–3 day intervals. During these controls we renewed the application of Hukinol at all test nests, although usually the smell of Hukinol was still perceptible over the whole nest areas.

In another field experiment we additionally tested the repellent effects of the second chemical substance, Hundeschreck. In particular, 32 artificial nests, each containing one small brown egg of the Domestic Fowl *Gallus gallus f. dom*., were randomly distributed in an industrial peat cutting field near Papenburg (Western Lower Saxony, Germany). Since this field was almost without any vegetation we painted the eggs with dark spots in the colour of the bare soil surface. In this way the eggs resembled the colour of clutches of Lapwing and Golden Plover, which use to breed in these habitats. Again, for later control we marked the nests with small sticks (height: 20 cm) in the way described above. Eleven nests were treated with Hukinol, and another 11 with the dog repellent Hundeschreck. The remaining 10 nests were used as controls. We applied the repellents in high concentration at four spots close to the nests, directly on the ground. The survival of the artificial nests was checked at day 1, day 5 and day 14 after exposure. Like in experiment I we renewed the repellents during each nest control.

In both experiments artificial nests were placed in fields without ground-breeding waders. The nests were considered to be depredated if eggs were clearly damaged by predators, or had disappeared (Bellebaum & Boschert 2003).

Experiment with real nests

In the three meadowbird reserves Leher Wiesen, Kuhdammoor-Melmmoor, and Vreeser Wiesen we searched for Lapwing nests by looking for breeding individuals or following birds when returning to their nests. Every second nest was treated with Hukinol in the way described above. Additionally, all nests were marked and checked at 3–5 days intervals. During these controls we renewed the application of Hukinol at all test nests.

Overall we monitored the survival of 38 Lapwing nests. Half of the nests were located in Leher Wiesen, the others in Kuhdammoor-Melmmoor (n = 12) and Vreeser Wiesen (n = 7). Nests were considered abandoned from unknown causes when the nest contents remained unchanged and adults were not present at two successive visits. Depredation was considered if one or all eggs were damaged by predators, or missing.

Statistics

Survival analyses were carried out to check for differences in the distribution of survival times between artificial nests treated with the repellents and untreated control nests. In particular, we used the Kaplan-Meier survivorship estimation to calculate the survival functions for the different treatments. Subsequently, we compared the survival of the different nest samples by using Cox's F-test for two samples (experiment I: Hukinol nests vs. control nests) and Gehan's Wilcoxon-test for multiple samples (experiment II: Hukinol nests vs. Hundeschreck nests vs. control nests).

With regard to the survival of Lapwing nests, we followed Mayfield (1961, 1975) by calculating daily survival rates for Hukinol-treated nests and control nests. Differences in daily survival of both groups were checked by Mayfield logistic regression (Aebischer 1999, Hazler 2004).

RESULTS

Artificial nest experiments

EXPERIMENT WITH HUKINOL

Within three weeks all artificial nests were depredated. Half of the losses already occurred in the first week after exposure (Fig. 1). With regard to a repellent effect of Hukinol we found no statistical evidence for a longer survival time of nests treated with the substance (Cox's *F*-test: $F_{1,32} = 1.182$, $P = 0.2$). Eggshell remains identified birds and carnivorous mammals as nest predators.

EXPERIMENT WITH HUNDESCHRECK AND HUKINOL

From 32 artificial nests which were randomly distributed in a peat cutting field only three survived after two weeks of exposure (Table 1). These had been treated with Hukinol or the dog repellent Hundeschreck. However, comparison of the survival times revealed no significant differences between nests treated with the repellents and controls (Gehan's-test for multiple samples: $\chi^2 = 1.95$, $df = 2$, $P = 0.377$). The eggs of most nests had completely disappeared. At least six eggshell remains showed bill marks of Carrion Crow, whereas five others had been depredated by carnivorous mammals. Additionally, we found footprints of Red Fox and Carrion Crow at several depredated nests. The daily survival rates of Lapwing nests showed marked differences between study sites. In Leher Wiesen most of the nests were successful, whereas in Kuhdammoor-Melmmoor the situation was the reverse (Table 2). However, due to small sample sizes the differences in nest survival between study sites was not significant (Mayfield logistic regression: $\chi^2 = 2.02$, $df = 2$, $P = 0.13$). Like in the artificial nest experiments we found no evidence for a longer survival of nests treated with Hukinol (Mayfield logistic regression: $\chi^2 = 0.005$, $df = 1$, $P = 0.946$). There

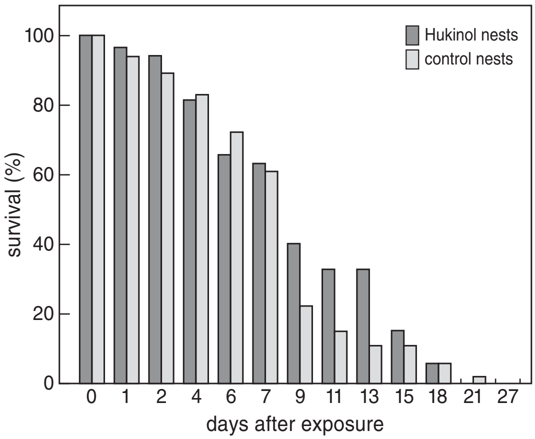

Figure 1. Survival (%) of artificial nests treated with Hukinol ($n = 17$) and control nests ($n = 17$) after exposure in an open grassland area near Esterwegen (Lower Saxony, Germany).

Table 1. Survival (%) of artificial nests treated with different odour repellents (Hukinol or Hundeschreck) and control nests in relation to days after exposure.

Days after exposure	treatment: Hukinol ($n = 11$)	Hundeschreck ($n = 11$)	Control ($n = 10$)
0	100	100	100
1	90.9	90.9	80
5	18.2	18.2	0
14	9.1	18.2	0

Table 2. Daily survival rates (means ± SD) for Lapwing nests treated with Hukinol and untreated control nests in 3 study sites in Western Lower Saxony (Germany).

Study sites	No. nests	Hukinol	Control
Leher Wiesen	19	0.996 ±0.0042	0.985 ± 0.0086
Kuhdammoor Melmmoor	12	0.957 ± 0.0217	0.979 ± 0.0152
Vreeser Wiesen	7	0.984 ± 0.0160	0.988 ± 0.0117
Overall	**38**	**0.985 ± 0.0062**	**0.984 ± 0.0065**

was, however, a clear difference in daily survival rate between Lapwing nests and artificial nests (Mayfield logistic regression: $\chi^2 = 35.73$, $df = 2$, $P < 0.001$). In particular, survival rates of artificial nests in both experiments were significantly lower compared to the real nests of Lapwing ($t > 6.02$, $P < 0.001$).

DISCUSSION

Since ground-nesting bird species are extremely vulnerable to nest predation, many evolved anti-predator behaviour, e.g. by attacking an approaching predator, breeding in colonies, and hiding the nest. In some species olfactory chemicals might help to reduce the risk of nest predation. Sandpipers (Scolopacidae), for instance, switch from monoester to diester preen waxes during courtship and incubation (Reneerkens *et al.* 2002). The same holds for wild-type and domesticated Mallards *Anas platyrhynchos* (Jacob *et al.* 1979, Kolattukudy *et al.* 1987). Since changes in preen wax composition in species with sex dimorphism in incubation is restricted to the incubating sex, Reneerkens and co-workers (2002) proposed that diester waxes might enhance olfactory crypticism of the nest. Another olfactory way in which ground-breeding sandpipers might prevent nests from predation is the defecation on eggs. In particular, Snipes *Gallinago gallinago* and Great Snipes *Gallinago media* were found to cover their nests with strong smelling faeces in the presence of approaching predators (Müller & Königstedt 1990). However, with regard to the noxious odours Hukinol and Hundeschreck none of our experiments revealed a significant effect of chemicals on survival of artificial and real nests as control nests and nests treated with repellents were depredated at the same rate. These results are in line with earlier investigations on other olfactory predator repellents, which either produced negative results or only had short-term effects (Lehner *et al.* 1976, Baker & Macdonald 1999, Smith *et al.* 2000).

Alternatively, the lack of efficacy of our odour repellents might be due to the experimental design and/or the behaviour of the predators. Previous investigations with animal feeding repellents convincingly demonstrated that the efficacy is related to the concentration of the repellent and the number and duration of its application (Nachman & Ashe 1973, Andelt *et al.* 1994, Macdonald & Baker 2004). In the present study we applied the odour repellents in high concentration and at short intervals of a few days. This way of application was in line with the instructions given by the producers of the repellents. Therefore, we suppose that the method of application was sufficient. Habituation to the repellents can also be excluded as explanation for the inefficacy of both chemicals because in all experiments predators were confronted with the repellents for the first time.

Since nest controls occurred at a high frequency, which left human scent at all nests, one may argue that these visits have caused high nest failure rates, especially in the experiments with artificial nests. In particular, predators might follow human scent-trails rather than being repelled by it. However, field experiments with different visit rates at Lapwing nests found no evidence for a reduction of clutch survival with increasing nest visits (Galbraith 1987, Fletcher *et al.* 2005, but see Teunissen *et al.* 2005b). These findings are in line with our own investigations, in which nests treated with Hukinol – a substance resembling strong human scent – were depredated at the same rate as controls.

The inefficacy of a predator repellent that resembles strong human scent is plausible in the light of habitat preferences of several carnivorous mammals: Red Fox and Stone Marten *Martes foina*, for instance, thrive even in large cities. Other species like Polecat *Mustela putorius* and Stoat *Mustela erminea* set up territories which often include farms and backyards of human settlements. The same holds for several avian predators, e.g. Magpie *Pica pica* and Carrion crow (see Schröpfer *et al.* 1984, Birkhead 1991, Mäck & Jürgens 1999, Reynolds 2000). Therefore, the lack of a repelling effect of human scent on these predators is not surprising. With regard to the ingredients of the dog repellent Hundeschreck, pelargonic acid and plant extracts, there is no support for a repelling effect on predators from the present study. Also Lehner and co-workers (1976) did not find a consistent repellence of acid-based chemicals in laboratory experiments with dogs and Coyotes.

Several comparative studies convincingly demonstrated that real and artificial nests are not depredated at the same rates (Weidinger 2001, Zanette 2002, Mezquida & Marone 2003). Similarly, we found significantly lower daily survival rates in artificial nests than in real Lapwing nests. The mechanisms underlying this difference are complex and have not been studied in all detail (Thompson III & Burhans 2003) The defensive behaviour of aggregations of breeding Lapwing pairs successfully excludes Carrion Crows from the nesting area. Consequently, predation rates of artificial nests are much lower within these aggregations than outside (Elliot 1985). Since our artificial nest experiments were exclusively carried out in fields and grasslands without nesting waders, this may have biased the estimates of daily survival rates. This does not affect the value of our experiments, as they were not designed to accurately estimate actual rates of nest predation in meadowbirds, but they provided an additional subset of results for testing the efficacy of two noxious odours as predator repellents.

In summary, our odour repellents show little promise to alter a predator's feeding behaviour in such a way that they durably reduce predation on target species. However, although a general repellence failed to appear, we cannot exclude at least a small temporary effect. Like visual and acoustic devices, noxious odours may rely on novelty and are bound to become ineffective due to habituation (compare Smith *et al.* 2000, Shivik *et al.* 2003).

ACKNOWLEDGEMENTS

This paper is dedicated to H.-H. Bergmann on the occasion of this 65th birthday. We are grateful to K.-H. Augustin, B. Düttmann, G. Düttmann, C. Kraft, M.C. Stiegel and B. Eulner for assistance in the field. We also wish to thank H. Schekkerman for comments on an earlier draft of the paper, and C. Bodenstein for assisting in the statistical analyses. The study was funded by Niedersächsisches Landesamt für Ökologie (Hannover).

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SAMENVATTING

Het gaat niet goed met de weidevogels in Europa. Mogelijk speelt predatie van eieren, jongen of oude vogels een rol bij de dalende trend van de aantallen weidevogels. De roep om "regulatie van predatoren" steekt daarom geregeld de kop op. Deze studie onderzocht de vraag of vieze geurtjes een afdoend middel kunnen zijn om predatoren op afstand te houden van nesten van bodembroeders. Daartoe werden experimenten gedaan met Hukinol (met een sterke mensengeur) en Hundeschreck, een ranzig ruikend product dat in de handel is als hondenverschrikker. In veldexperimenten met kunstnesten uitgevoerd in het open landschap van Nedersaksen (Duitsland) bleek geen verschil in overlevingskans tussen nesten die behandeld waren met deze geurstoffen en de controles: vrijwel alle kunstnesten waren binnen enkele dagen verdwenen. Ook bij een experiment met nesten van de Kievit *Vanellus vanellus*, waarin de helft van de nesten met Hukinol was behandeld en de andere helft als controle diende, kwam geen verschil tussen behandelingen naar voren. Geconcludeerd wordt dat geen van beide stoffen effectief is om het mislukken van nesten van bodembroeders te voorkomen. (JS)

Corresponding editor: Julia Stahl
Received 10 August 2005; accepted 20 January 2007