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Effect of cattle trampling on ground nesting birds on pastures: an experiment with artificial nests

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ABSTRACT

1. In semi-natural grasslands, nest trampling by cattle can have a strong effect on hatching success but the relationship linking cattle density, incubation time and nest survival has for now only been hypothesized.
2. Based on an experiment with artificial nests, the objective of this study was to test the theoretical model generally used to estimate nest survival. In spring 2009, we conducted a one-month experiment on permanent grasslands of the French western marshlands grazed at three different stocking rates (1 LU.ha-1, 2 LU.ha-1 and 4 LU.ha-1).
3. The results confirmed that trampling depended on stocking rates.
4. Trampling had a major effect on nest survival (32–85% of nests destroyed).
5. The theoretical model classically used by managers and modellers proved to be a good approximation of the dynamics of nest trampling.
6. Synthesis and applications: We conclude that nest trampling has a major impact on nest survival in pastures and that the use of such a model could help managers to define acceptable levels of cattle densities.

KEYWORDS

INTRODUCTION

European grasslands are anthropic ecosystems highly dependent on agricultural practices and cannot be maintained without farming. However, like in most other agroecosystems, grassland biodiversity has suffered from a steep decline due to intensification of farming practices (Vickery et al. 2001). Ground nesting birds like waders capture this dual effect of grassland management on biodiversity particularly well: on the one hand, these birds have specific habitat requirements, implying relatively short grass heights in spring that need a minimal grazing pressure (Durant et al. 2008); but on the other hand, high cattle densities increase risks of nest trampling and reduce hatching success (Beintema & Muskens 1987). Cattle, therefore, interact in a dual way with birds: as an ecosystem engineer (facilitation) and through nest trampling (amensialism). Recent studies based on dynamic models of grassland agroecosystems suggest that a fine adjustment of grazing sequences would make it possible to balance these two effects (Sabatier et al. 2010), mainly by an anticipation of grazing before the nesting period of the birds at stake. However, such mechanistic models are highly dependent on the underlying hypotheses made on biological mechanisms, while knowledge of these mechanisms is often lacking.

In this study, we addressed more specifically the mechanism of nest trampling that is at the core of the interactions between grassland management and dynamics of ground nesting birds. This mechanism is most of the time modelled considering an independence of the events: *{being trampled by one animal during one day}*, either explicitly (Guthery & Bingham 1996; Sabatier et al. 2010) or implicitly (Green et al. 1997). Many studies have tried to quantify trampling effects (e.g. Bareiss et al. 1986; Paine et al. 1996; Pavel 2004) but until now, no study had recorded the dynamics of trampling to test if this hypothesis of independence was a good approximation of reality.

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The main objective of this study was, therefore, to test if the base model of Guthery and Bingham (1996) led to a good approximation of the trampling dynamics of artificial nests. We designed an experiment to record the effect of cattle stocking rate on nest trampling in a dynamic way and to test how the theoretical model of Guthery and Bingham (1996) fits our data. We then extrapolate our experimental results to estimate the effect of cattle density on egg loss due to trampling for three patrimonial waders of our study area: the Northern Lapwing (*Vanellus vanellus*), the Common Redshank (*Tringa totanus*) and the Black-Tailed Godwit (*Limosa limosa*). We finally discuss the implications for management in the context of the dual effect of grazing on birds.

1. METHODS AND MATERIALS

1.1. Study area

The experiment was conducted on the Saint-Laurent de la Prée (INRA) experimental farm. This experimental farm is an extensively managed beef-cattle operation typical of the study area. It is located in the 'dry marshes' (i.e. polders with controlled water levels, mainly devoted to agriculture: field crops and grasslands) of Rochefort-sur-mer on the French Atlantic coast (0°02'28"W; 45°58'52"N, at sea level).Grasslands are characterised by a high (5 t dry matter/ha on average) but seasonal productivity as soil and climatic conditions induce specific constraints on grass production. Grass growth is usually halted by water deficits in summer and by low temperature in winter, thus it generally occurs from April to June.

1.2. Experiment

The experiment was conducted from 21 April to 19 May 2009. It was based on six fields grazed by pairs of cows and calves and managed with three increasing stocking densities (1 Livestock units (LU).ha^{-1}, 2 LU.ha^{-1} and 4 LU.ha^{-1}; Table 1). Due to slight differences in field sizes, the desired instant cattle densities could not always be reached (e.g. field T1.1) but were kept as close as possible from the target.

Artificial nests (Fig. 1) were designed to mimic real nests. They consisted in small (≈10 cm) radius cavities hosting four snail shells of *Helix pomatia* standing for the average number of eggs in a clutch (Ottvall 2004). Empty snail shells were preferred to eggs as in Paine et al. (1996) or Bareiss et al. (1986) to avoid predation by foxes or crows, for example, and focus on the effect of trampling. The need to conduct a daily survey of nests prevented us from using buried clay discs as in Mandena et al. (2013) as these could not have been checked every day. Empty snail shells were also preferred to clay discs laid directly on the ground as in Koerth et al. (1983) and Jensen et al. (1990) or to jam-jar caps as in Pavel (2004) to avoid stimulating the curiosity of the animals by introducing artificial elements to their environment. The use of snail-shells, however, could have induced snail-specific predation. To account for this risk in the study, we recorded disappeared and predated shells (26 in total) and replaced them by new ones the day we recorded it. Explicitly representing the eggs in the nest made it possible to limit the dependency of nest trampling to its size

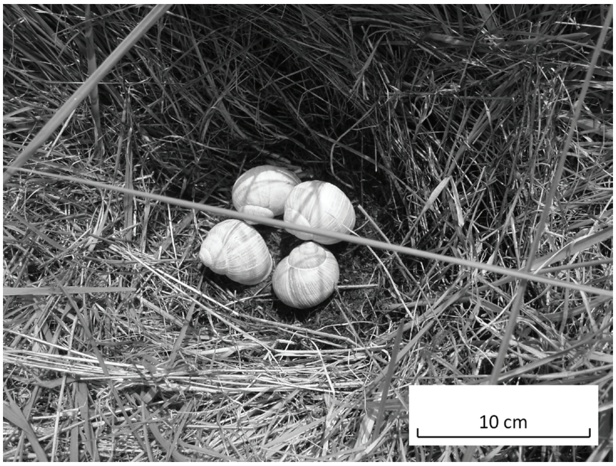

Figure 1. Picture of an artificial nest.

Table 1. Experimental plan

Field	Treatment	Field size (ha)	Number of cows and calves couples	Cattle density (LU.ha^{-1})	Number of nests
T1.1	T1	1,63	2	1,2	30
T1.2	T1	2,00	2	1,0	29
T2.1	T2	2,00	4	2,0	31
T2.2	T2	2,00	4	2,0	28
T3.1	T3	1,97	8	4,1	26
T3.2	T3	2,00	8	4,0	29

that would have been expected with a clay disc or any other form of artificial nest (Pakanen et al. 2011). To avoid attracting cattle, locations of the nests were not marked with flags or any other mark. This implied that artificial nests had to be placed following a regular pattern that could be easily followed by the observer. To minimise biases due to this non-random location of artificial nests, nests were placed along a transect, every 7 m, alternatively on the right and on the left side of the transect, at 4 m from the transect. Transects were located on one of the diagonals of each field so as to locate nests both on edges and in the centre of the field. The choice of the diagonal was made to avoid structures acting as attractors for cattle (water source, gate …) resulting in over-trampled areas, unsuitable for nesting. Due to differences in field shapes, lengths of diagonals varied and number of nests were chosen not to have transects longer than 200 m. Nests were placed in the fields a few hours after the cows entered them to avoid over-trampling at the beginning of the experiment due to the initial exploring behaviour of the animals. Nest placement did not induce any modification of cattle behaviour, leading to a modification of nest trampling (no over-trampling on the first day).

1.3. Analyses

Testing the effect of stocking rates: In a first step, trampling data were transformed into survival estimations $S(t)$ using the Kaplan–Meyer method (Lee & Wang 2003). $S(t)$ is recursively estimated as follows:

$$S(t+1) = S(t)\left(1 - \frac{D(t+1)}{N(t+1)}\right) \qquad \text{(eqn 1)}$$

with $D(t)$ the number of nests trampled at time t, $N(t)$ the number of nests that had not been trampled until $t - 1$ and $S(0) = 1$. Curves were then compared within and between treatments using the non-parametric Logrank test adapted to the comparison of survival data (Lee & Wang 2003). Survival analyses were computed with the ‘survival’ package (Thernau & Grambsch 2000) of the R software (R Core Team 2015). For readability, we will often speak of trampling rates defined as $1\text{-}S$ in the rest of the study.

Testing the validity of the base model: In a second step, the trampling rates were used to calibrate and test the validity of the theoretical base model developed by Guthery and Bingham (1996). This model assumes independence of the animals in their grazing behaviour as well as independence of their grazing behaviour in time and is expressed as follows:

$$T(t,u)=1-(1-q)^{u,t} \quad \text{(eqn 2)}$$

with T the trampling rate, t the length of the trampling period, u the cattle density in LU.ha^{-1} and q the trampling coefficient, a constant equal to the trampling rate due to 1LU.ha^{-1} in 1 day. Estimation of q was performed for the different treatments using a least square method. For each estimation of q, the root mean square error (RMSE) was computed. Estimates of q were then compared two by two using Mann-Whitney non-parametric tests and the different models were visually compared to the data.

Link to nest survival for three common species: In the final step, effects of the different treatments on trampling rates were analysed regarding their potential effects on nest survival in face of trampling for three patrimonial grassland birds of our study area: Common Redshank (*Tringa totanus*; Least Concern IUCN 2015), Northern Lapwing (*Vanellus vanellus*; Least Concern IUCN 2015) and Black-Tailed Godwit (*Limosa limosa*; Near Threatened IUCN 2015). For each species, we computed the nest survival over the whole incubation period for cattle densities ranging from 0 to 10 LU.ha^{-1} based on eqn 2. To model nest survival, we used values of trampling coefficients q obtained from the observation of real nests in different European contexts (Beintema & Muskens 1987; Liker & Szekely 1997; Hart et al. 2005; Ottvall 2005; review in Pakanen et al. 2011) and lengths of incubation periods found in Cramp and Simmons (1983). Numerical computations were performed with Python 2.7.2 (von Rossum & de Boer 1991).

2. RESULTS

2.1. Survivals and trampling rates

The first series of results confirmed that trampling rates differed between treatments. Fields of treatment T3 (4 LU.ha^{-1}) showed the highest percentage of nests trampled (mean percentage of nest trampled at the end of the experiment = 85.0 %) followed by fields of treatment T2 (2 LU.ha^{-1}) that had an intermediate percentage of nests trampled (69.75 %) and finally fields of treatment T1 (1 LU.ha^{-1}) showed the lowest percentage of nest trampled (32.25 %). Trampling frequencies in the three treatments significantly differed (Chi-square test, $p<10^{-3}$). Comparison of the Kaplan-Meyer estimations of survivals (Fig. 2) confirmed this finding. The survivals did not show any significant difference within each treatment (Logrank test ; $p=0.78$ in T1, $p=0.17$ in T2 and $p=0.13$ in T3) but differed among treatments (Logrank test ; $p<10^{-3}$) and were ranked in the same order. These results confirm that trampling rates increase with cattle density.

2.2. Model of trampling rate

The second series of results showed that the base model of Guthery and Bingham (1996) gave a good approximation of the dynamic of trampling observed in our experiment. Different estimations of parameter q (trampling coefficient) gave similar values and low RMSE (<0.1; Table 2). The values of parameter q did not significantly differ between treatments (Mann and Whitney Test; $p = 0.35$). The model of Guthery and Bingham (1996) gave a good visual fit (Fig. 2) and low RMSE (Table 2), with the average value of $q = 0.0182$. The curves obtained with the average trampling coefficient were very similar to the ones obtained with the trampling coefficients specific to the different treatments (Fig. 2).

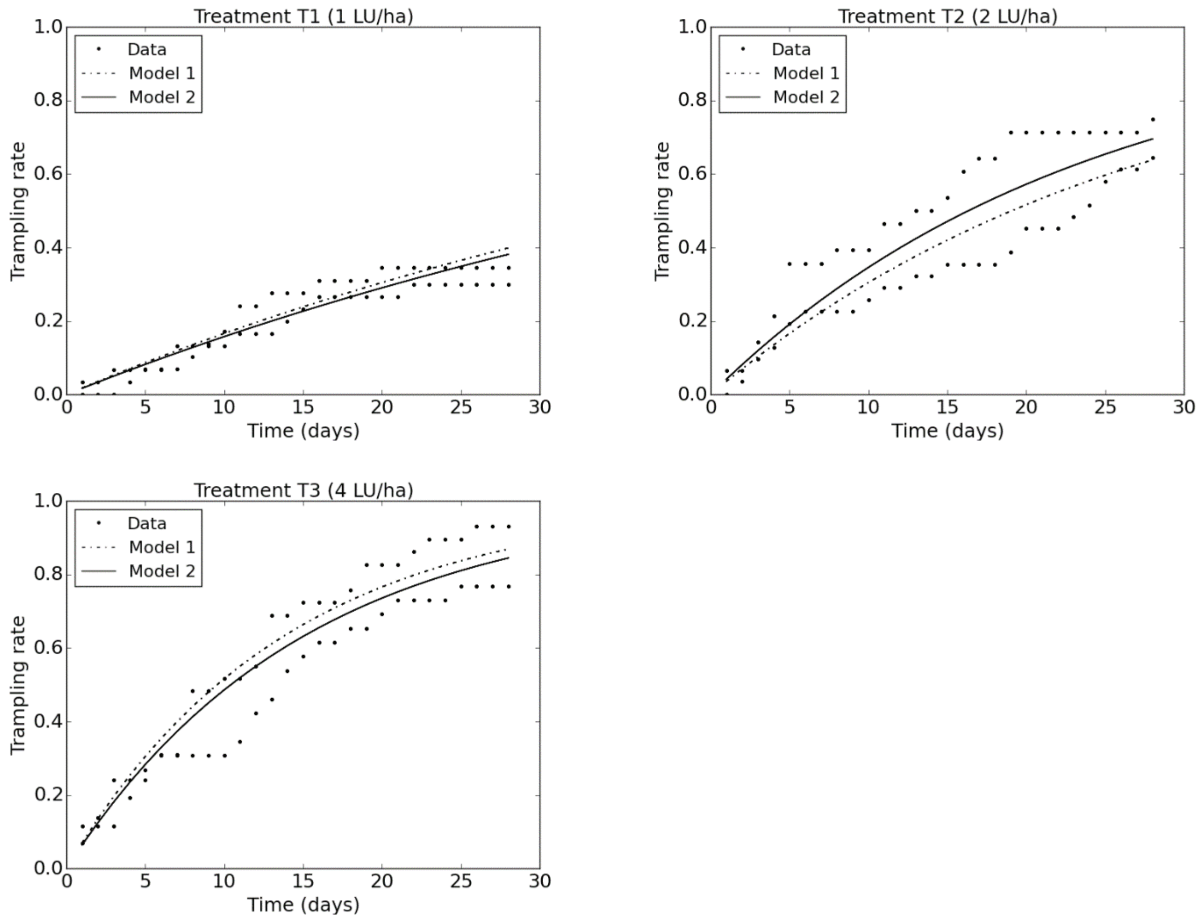

Figure 2. Observed and modeled trampling rates. Black dots represent the trampling rates observed in the two fields of each treatment. Black dashed lines (Model 1) correspond to the trampling rates modeled with the trampling coefficient q based on the data of the three treatments. Continuous grey lines (Model 2) correspond to the trampling rates modeled with the trampling coefficient q based on the data of the given treatment.

Table 2. Estimations of parameter q (the trampling coefficient) and associated RMSE (Root Mean Standard Error) of the model.

	Cattle density	*q*	RMSE
T1	1	0,0169	0,0367
T2	2	0,0213	0,0985
T3	4	0,0165	0,0767
Mean	-	**0,0182**	**0,0810**

2.3. Links to waders' dynamics

The results on trampling rates could be interpreted in terms of their impacts on bird demographic parameters, for three common waders of our study area (Fig. 3). A first overview of the result shows that the nest survival quickly decreases with increased cattle density. The Northern Lapwing is the species the least impacted by trampling, followed by the Black-Tailed Godwit and finally the Common Redshank is the most sensitive to trampling. As an example, with a cattle density of 1.5LU.ha^{-1} over the whole incubation period, nest survival of the Northern Lapwing is expected to reach approximately 50% while nest survival of the Black-Tailed Godwit is expected to reach approximately 35% and nest survival of the Common Redshank is expected to reach approximately 25%. The high variability of model outputs to the value of parameter *q* illustrates the high sensitivity of the model to this parameter.

3. DISCUSSION

3.1. Values of the trampling coefficients

Many studies have tested the effects of trampling on nest survival but have largely been limited to a global assessment of percentage of nest trampled without explicit references to stocking rates. It is only recently that standardized studies were conducted to estimate values of trampling coefficients (*q* in the present study). The study of Pakanen et al. (2011) provides the detailed list of these studies to which the more recent study of Mandema et al. (2013) should be added. The article by Pakanen et al. (2011) gives daily trampling rates (q^u with our notations) and corresponding cattle densities *u* from which we could infer the trampling coefficients *q*. These studies predict

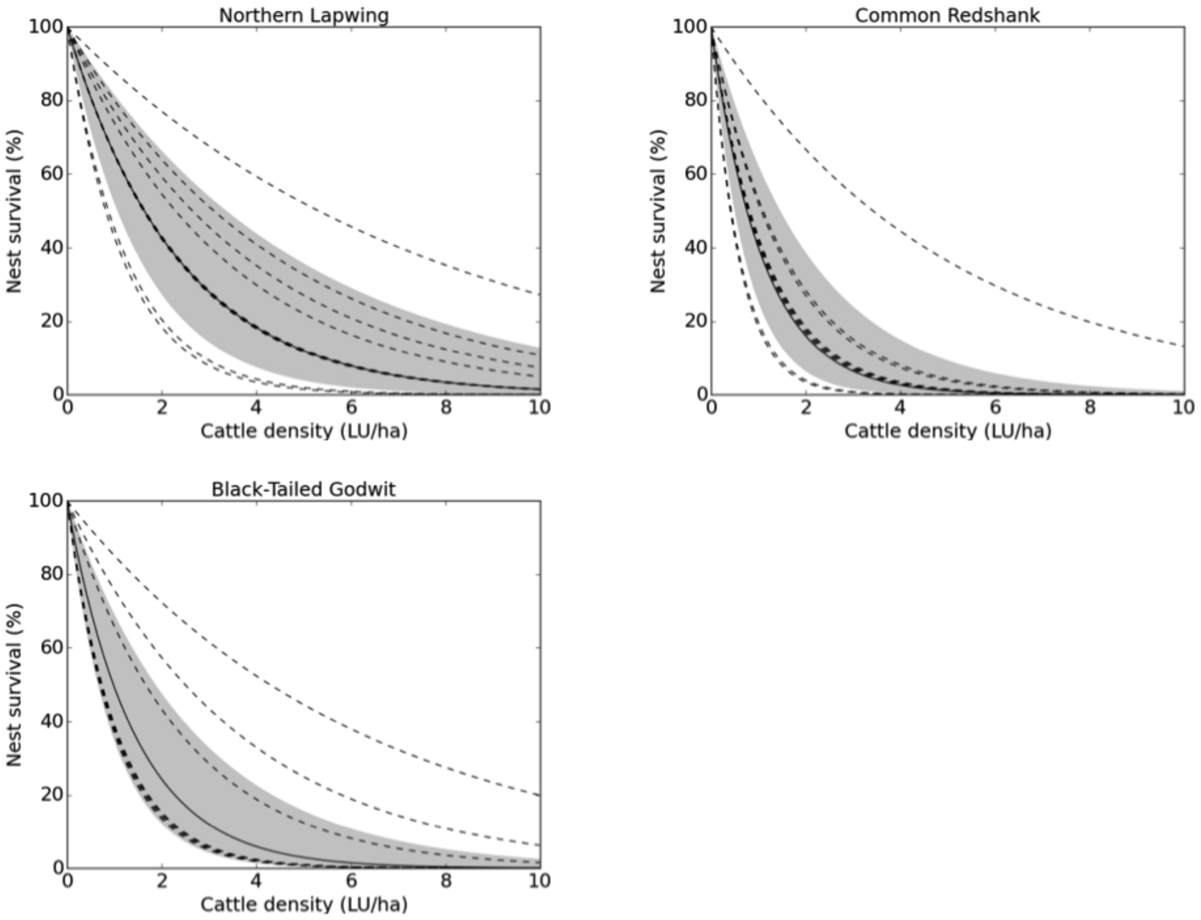

*Figure 3. Estimation of nest survival as a function of cattle density for three patrimonial waders of the study area (Northern Lapwing, Common Redshank and Black-Tailed Godwit). Dashed lines correspond to relationships estimated with the different values of the trampling coefficient (q) found in the literature (*Beintema and Muskens 1987, Liker and Szekely 1997*,* Hart et al. 2005, Ottvall 2005*; review in* Pakanen et al. 2011*). Continuous lines are the relationships estimated with a trampling coefficient (q) equal to the mean of these values. The grey area is delimited by the relationships estimated with a trampling coefficient (q) equal to the mean +/- standard deviation of these values.*

a trampling coefficient *q* ranging from 0.002 to 0.046 (mean = 0.026; sd = 0.018) similar to the one found in our study (*q* = 0.018 on average), although very variable. This high variability and the difference with our study can be explained by environmental factors such as grassland productivity or time of the year or by species specific factors such differences in nest size or in defensive behaviour among species (Pakanen et al. 2011). Defensive behaviour was mainly documented in situations of defense against predators (e.g. Smith et al. 2012) and has been shown to drastically reduce predation rates (Göransson et al. 1975). It is likely that this defensive behaviour also reduces nest trampling by keeping the cattle away from nests. Indeed, Northern Lapwing and Black-tailed Godwit that showed the lowest trampling rates are well known for their active defensive strategies towards predators (Black-tailed godwit: Green et al. 1990, Dyrcz et al. 1981; Northern Lapwing: Kis et al. 2000) while the Common Redshank is considered less aggressive (Cervencl et al. 2011; Dyrcz et al. 1981).

3.2. Implication for bird conservation

Our results confirm that nest trampling by cattle may have a strong negative impact on nest survival. A simplistic conclusion would be to advocate for cattle exclusion during the nesting stage of birds. However, one shall also keep in mind that grazing is compulsory to create suitable sward heights for grassland birds (review in Durant et al. 2008) and (ii) that spring is a time of the year on which farmers strongly rely for cattle feeding. In other words, a full removal of grazers is expected to be detrimental to both bird dynamics and agricultural production. A model like the one tested in this study provides a solution to determine what levels of grazing remain acceptable for bird conservation. We show that the simple model hypothesising independence of events *{being trampled by one animal during one day}* proposed by Guthery and Bingham (1996) given in eqn 2 is accurate enough to simulate nest survival through time as a function of cattle density. With this model, accuracy in the estimation of parameter *q* is of utmost importance since small variations in its value may result in high difference in predicted nest survival, especially for cattle densities ranging from 0.5 to 4 (Fig. 3). This is due to the fact that this parameter is raised at the power of u (the cattle density) and t_{inc} (the length of the incubation period). Literature shows that this parameter strongly depends on case study specific conditions such as the bird species considered or the type (species and age) of animal grazing (Beintema & Muskens 1987). Given the high importance of this parameter, and the lack of quantitative information on its dependency to environmental factors, we advise managers to estimate this trampling coefficient in the field as accurately as possible before applying the model to their situation. Once estimated, it can be used to compute expected nest survival for a given cattle density or used in more complex models to simulate bird dynamics. Dynamic modelling studies addressing this issue showed, for instance, that anticipated grazing occurring before the nesting period was a way to balance the two positive and negative effects of grazing (Sabatier et al. 2010). In particular, heavy autumn grazing has been shown to create short grass heights favourable to precocious birds like the Northern Lapwing (Tichit et al. 2005).

4. CONCLUSION

Our results showed that stocking rate can have a strong effect on nest trampling and that the model classically used to represent this effect gave a good approximation of what could be observed in the field, and, therefore, it is a powerful management tool. However, these results also show the high sensitivity of the model to the estimation of the key parameter (trampling coefficient). For management, this means that an accurate estimation of the trampling coefficient shall be done and that management rules shall be regularly adapted with years while knowledge on this parameter increases. Although not a direct result of this study, we also stress the importance of keeping in mind the dual effect of grazing on grassland birds and to adjust carefully grazing sequences to balance the negative (trampling) and positive (creating suitable habitat) effects of grazing.

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REFERENCES

Bareiss, LJ. (1986) Effects of short-duration and continuous grazing on Bob-white and Wild Turkey nesting. Journal of Range Management, 39, 259-260.

Beintema, A.J. & Muskens, G.J.D.M. (1987) Nesting Success of Birds Breeding in Dutch Agricultural Grasslands. The Journal of Applied Ecology, 24, 743-758.

A., Esser, W., Maier, M., Oberdiek, N., Thyen, S., Wellbrock, A. & Exo, K.M. (2011) Can differences in incubation patterns of Common Redshanks *Tringa totanus* be explained by variations in predation risk? Journal of Ornithology, 152, 1033-1043.

Cramp, S. & Simmons, K.E.L. (1983) The Birds of the Western Palearctic: Volume III. New York: Oxford University Press.

Dyrcz, A., Witkowski, J. & Okulewewicz, J. (1981) Nesting of “timid” waders in the vicinity of “bold” ones as an antipredator adaptation. Ibis, 123, 542-545.

Durant, D., Tichit, M., Kerneïs, E. & Fritz, H. (2008) Management of agricultural wet grasslands for breeding waders: integrating ecological and livestock system perspectives–a review. Biodiversity Conservation, 17, 2275-2295.

Göransson, G., Karlsson, J., Nilsson, SG. & Ulfstrand, S. (1975) Predation on Birds’ Nests in Relation to Antipredator Aggression and Nest Density: An Experimental Study. Oikos, 26, 117-120.

Green, R.E., Hirons, G.J.M. & Kirby, J.S. (1990) The effectivness of nest defence by Black-Tailed Godwits *Limosa limosa*. Ardea, 78, 405-413.

Green, R.E., Tyler, G.A., Stowe, T.J. & Newton, A.V. (1997) A simulation model of the effect of mowing of agricultural grassland on the breeding success of the corncrake (*Crex crex*). Journal of Zoology, 243, 81-115.

Guthery, F.S., & Bingham, R.L. (1996) A theoretical basis for study and management of trampling by cattle. Journal of Range Management, 49, 264-269.

Hart, J.D., Milsom, A., Baxter, A., Kelly, P.F. & Parkin, W.K. (2005) The impact of livestock on Lapwing *Vanellus vanellus* breeding densities and performance on coastal grazing marshes. Bird Study, 49, 67-78.

Jensen, H.P., Rollins, D. & Gillen, R.L. (1990) Effects of cattle density on trampling loss of simulated ground nests. Wildlife Society Bulletin, 18, 71-74.

Kis, J., Liker, A. & Szekely, T. (2000) Nest defence by lapwings: Observations on natural behaviour and an experiment. Ardea, 88, 155-163.

Koerth, B.H., Webb, W.M., Bryant, F.C. & Guthery, F.S. (1983) Cattle trampling of simulated ground nests under short duration and continuous grazing Texas. Journal of Range Management, 36, 385-386.

Liker. A., & Szekely, T. (1997) The impact of grazing and road use on hatching success of lapwings (*Vanellus vanellus*). Acta zool. Acad. Sci. Hung., 43, 85-92.

Lee, E.T. & Wang, J. (2003) Statistical Methods for Survival Data Analysis (Vol 476). Hoboken, New Jersey: John Wiley & Sons.

Mandema, F.S., Tinbergen, J.M., Ens, B.J. & Bakker, J.P. (2013) Livestock grazing and trampling of birds' nests: an experiment using artificial nests. Journal of Coastal Conservation, 17, 409-416.

Ottvall, R. (2004) Population ecology and management of waders breeding on coastal meadows. PhD Thesis, University of Lund.

Ottvall, R. (2005) Boöverlevnad hos strandängshäckande vadare–den relativa betydelsen av predation och trampskador av betesdjur. Ornis Svecica, 15, 89-96.

Paine, L., Undersander, D.J., Sample, D.W., Bartelt, G.A. & Schatteman, T.A. (1996) Cattle trampling of simulated ground nests in rotationally grazed pastures. Journal of Range Management, 49, 294-300.

Pakanen, V.M., Luukkonen, A. & Koivula, K. (2011) Nest predation and trampling as management risks in grazed coastal meadows. Biodiversity Conservation, 20, 2057-2073.

Pavel, V. (2004) The impact of grazing animals on nesting success of grassland passerines in farmland and natural habitats: a field experiment. Folia Zoologica, 53, 171-178.

Sabatier, R., Doyen, L. & Tichit, M. (2010) Modelling trade-offs between livestock grazing and wader conservation in a grassland agroecosystem. Ecological Modelling, 221, 1292-1300.

Smith, P.A., Tulp, I., Schekkerman, H., Gilchrist, H.G. & Forbes, M.R. (2012) Shorebird incubation behaviour and its influence on the risk of nest predation. Animal Behaviour, 84, 835-842.

Therneau, T.M. & Grambsch, P.M. (2000) Modeling Survival Data: Extending the Cox Model. New York: Springer.

Tichit, M., Renault, O. & Potter, T. (2005) Grazing regime as a tool to assess positive side effects of livestock farming systems on wading birds. Livestock Production Science, 96, 109-117.

van Rossum, G. & de Boer, J. (1991) Interactively Testing Remote Servers Using the Python Programming Language. CWi Quarterly, 4(4), 283-303.

Vickery, J.A., Tallowin, J.R., Feber, R.E., Asteraki, E.J., Atkinson, P.W., Fuller, R.J. & Brown, V.K. (2001) The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food resources. Journal of Applied Ecology, 38, 647-664.