Belg. J. Zool. - Volume 127 (1997) - issue 2 - pages 191-195 - Brussels 1997

SHORT NOTE

EFFECTS OF SOIL ACIDIFICATION ON REPRODUCTIVE SUCCESS IN GREAT TITS BREEDING IN FORESTS ON NUTRIENT-POOR SOILS IN FLANDERS, BELGIUM

RIANNE PINXTEN AND MARCEL EENS

Department of Biology, University of Antwerp, U.I.A., Universiteitsplein 1, B-2610 Wilrijk, Belgium.
e-mail: eens@uia.ua.ac.be

Key words: Acid rain, soil acidification, eggshell, *Parus major*.

It has been recently shown that on nutrient-poor, acidified soils in the Netherlands an increasing number of great tits, *Parus major* (LINNAEUS, 1758), and other forest passerines produce eggs with thin and porous shells and have low reproductive success as a result of calcium deficiency (1, 2). In a mixed deciduous-coniferous forest on nutrient-poor sandy soil, representative of 80% of the Dutch forests, the proportion of great tits laying eggs with defective shells increased from 10% in 1983-1984 to 40% in 1987-1988 (15). A similar increase in eggshell defects and associated laying irregularities have been reported for tits and other species in Europe and in North America (3, 4, 5, 6, 7, 8, 9). The causes of this phenomenon have been studied in detail in great tits in the Netherlands (1, 2, 10, 11).

Female granivorous and insectivorous birds, including great tits, apparently depend on a high level of dietary calcium during the laying phase, which they normally obtain through the uptake of snail shells or other calcium-rich items (2, 10, 12, 13). Atmospheric deposition of acidifying compounds («acid rain») has caused a decline in snail populations on poorly buffered sandy soils, because calcium needed for shell formation becomes unavailable. This decrease in snail abundance on nutrient-poor soils caused by man-made acid rain has been demonstrated to be responsible for the decline in eggshell quality in great tits breeding in forests on nutrient-poor soils (11). In forests with a scarcity of snails and high rates of eggshell defects, some of the birds try to compensate for the lack of snail shells by using anthropogenic calcium sources such as chicken eggshells and mortar that they obtain outside the forest at farms and picnic sites.

Although the detailed studies of Graveland in the Netherlands (1, 2, 10, 11) provide evidence that calcium deficiency can be a widespread phenomenon in many acidified areas, there are very few data to support this claim. This is due to several reasons (see 11), an important one being that eggshell defects are hard to recognize for the untrained eye and also may be overlooked because eggs with defective shells are often removed by the parents. Also, in most countries study sites are usually situated close to human settlements, where calcium deficiency is unlikely to occur due to the presence of anthropogenic calcium sources. Determining the extent of calcium deficiency in other countries, and especially in remote areas where anthropogenic calcium sources are not available, should be a first priority (11).

To our knowledge, the occurrence of this phenomenon has not been investigated or reported in Belgium. Here, we report the results of a preliminary study on the effects of soil acidification on the eggshell quality and reproductive success in great tits breeding in a forest on nutrient-poor sandy soil in a relatively remote area in Flanders, Belgium.

The study was conducted in 1995 in a coniferous forest on nutrient-poor sandy soil in the Nature Reserve «De Kalmthoutse Heide (The Kalmthout Heath)» in Kalmthout (4° 25' N, 51° 25' E), situated about 40 km north-west of Antwerp. At the end of February 1995, we erected 21 nestboxes for great tits in a coniferous forest, situated near the border with The Netherlands. The pH-H_2O (1:2) value of the soil in this study site was measured and varied between 3 - 4. The study site in the Kalmthoutse Heide can be considered as a remote area, since nearly all nestboxes were situated more than 500 m from human settlements in the neighbourhood (mainly farms) and it has been shown that great tits do not travel more than 500 m away from their nest site in search of anthropogenic calcium sources (2). In 1995, we also studied the occurrence of egg-shell defects in a great tit population breeding in a nest-box colony (23 nestboxes) on nutrient-rich soil on the University Campus of the University of Antwerp in Wilrijk. The latter control study site, with a pH-H_20 (1:2) value of 6, is situated very close to human settlement. In both study sites nestboxes were checked every 4 to 5 days from the moment nesting material appeared. When eggs were present in the nestbox, the quality of the shell of each individual egg was evaluated. We distinguished between eggs with a normal shell and eggs with a deviant shell. Eggs with deviant shells can be recognized by their rough, dull shell surface and aberrant pigmentation (Fig. 1; Table 1). All eggs in a nest were individually numbered to determine the hatching success of each egg.

TABLE 1

Criteria used to evaluate the shell quality of eggs of great tits (after Graveland, 1993).

normal shell	deviant shell
– Clearly distinguishable spots. Eggs are very rarely entirely white.	– Smeared spots. There is a pink bloom on (part of) the egg. Sometimes eggs are entirely white.
– Shell surface is smooth and glossy.	– Shell surface is rough and dull.
– Pigmentation is usually evenly distributed on shell surface. Sometimes there is a wreath of pigmentation around the blunt top of the egg, but the spots are always clearly and separately recognizable.	– Pigmentation is almost always concentrated around the blunt top of the egg.
– There are never holes in the egg.	– Sometimes holes in the egg are visible with the naked eye.
– Egg is never desiccated.	– Egg is usually in the process of desiccation. Often, the desiccation can already be observed during the laying period because the air chamber enlarges quickly.

Eggs with normal shells never become desiccated. Eggs with deviant shells often become desiccated. As a result of desiccation the content of the egg drops to one side. In extreme cases, the content will become separated from the shell.

Fig. 1. – Deserted clutch of Great Tit containing one egg with a defective shell (top right) and two eggs with normal shells. Photograph: with permission from Jaap Graveland.

Data were analysed using the statistical packages SPSS/PC and StatXact-Turbo with standard techniques (14). Data expressed as percentages were arcsine square-root transformed to normalize.

In total 6 out of 16 (38%) females breeding on nutrient-poor soil in the Kalmthoutse Heide produced eggs with defective shells, compared to none of the 21 females breeding on the University Campus on nutrient-rich soil (X^2=9.40, P<0.01). When comparing the proportion of aberrant eggs between the two study sites, 19 (14%) out of 138 eggs in the Kalmthoutse Heide had a deviant shell compared to none out of 207 eggs on the University Campus in Wilrijk (X^2= 30.16, P<0.0001). In the Kalmthoutse Heide the proportion of eggs with defective shells in the six clutches containing deviant eggs was on average 42%, and varied from 9% to 67%. Only 14% (3 out of 19) of the eggs with deviant shells hatched, compared with 98% (115 out of 119) of normal eggs. This difference in hatching success between the two egg categories is highly significant (X^2=86.42, P< 0.0001). Twelve of the 16 eggs with defective shells that did not hatch, became desiccated during the laying or the early incubation period, two eggs did not hatch due to shell breakage, one egg disappeared from the nest and one egg did not hatch as a result of the clutch being deserted. Within the Kalmthoutse Heide, the hatching success of clutches containing one or more eggs with deviant shells (0.48 ± 0.34 SD, N=6) was significantly lower than that of clutches with only normal eggs (0.99 ± 0.04, N=10; t-test, t=-5.46, df=14, P<0.0001). The overall hatching success of clutches on the Kalmthoutse Heide was 0.80 ± 0.32 (N=16), compared to 0.97 ± 0.06 (N=21) for clutches on the University Campus in Wilrijk. This difference in hatching success between both study sites is significant (t-test, t=-2.22, df=35, P=0.033).

Although our results are based upon a one-year study, they strongly suggest that soil acidification and calcium deficiency also limit breeding success of great tits breeding in relatively remote areas on nutrient-poor soils in Flanders. We found that 38% of the studied great tit females in acidified forests in the «Kalmthoutse Heide» produced eggs with defective shells, resulting in a significantly reduced hatching success. These results are comparable to those reported by Graveland for the Netherlands (1,15).

In the sixties, reductions in egg-shell thickness were always attributed to DDT and other organochlorines (16,17). However, GRAVELAND & DRENT (2) concluded that it is very unlikely that the increase in eggshell defects in the Netherlands during the past two decades was due to poisoning by organochlorine compounds such as DDT, since raptors are more vulnerable to poisoning than passerines (18) and raptors have fully recovered since the banning of DDT and related compounds in the Netherlands (19).

From Graveland's study, it follows that great tits may be good candidates for use as indicators of the effects of (progressive) soil acidification on birds, and for measuring the effectiveness of measures to be taken to improve the situation (7). It is obvious, however, that more research is needed on a great variety of species. For instance, the black tern, *Chlidonias niger*, has completely disappeared as a breeding species from the 'Kalmthoutse Heide' since the sixties (20, 21), although there have been little or no apparent changes in habitat. It has recently been shown, however, that this species suffers severely from calcium deficiency in certain habitats in the Netherlands (22). Chicks grew well during the first week but then started to develop deformed legs and wings. Postmortem analysis revealed severe rachitis. Additional evidence of calcium deficiency came from higher incidences of incomplete clutches, eggs failing to hatch and the occurrence of eggs with aberrant colouration patterns, as in calcium-deficient great tits (22).

REFERENCES

1. GRAVELAND , J., R. VAN DER WAL, J.H. VAN BALEN & A.J. VAN NOORDWIJK (1994) – Poor reproduction in forest passerines from decline of snail abundance on acidified soils. *Nature*, **368**: 446-448.
2. GRAVELAND, J. & R.H. DRENT (1997) – Calcium availability limits breeding success of passerines on poor soils. *J. Anim. Ecol.*, **66**: 279-288.
3. SMITH, J. (1990) – Acid rain and defective eggshells. *Anser*, **29**: 158.
4. WINKEL, W. & H. HUDDE (1990) – Zum vermehrten Auftreten von «Bruten in leerem Nest»: Befunde am Meisen (*Parus*) und andere Höhlenbrütern aus verschiedenen Untersuchungsräumen Norddeutschlands. *Vogelwarte*, **35**: 341-350.
5. GLOOSCHENKO, V., P. BLANCHER, J. HERSKOWITZ, R. FULTHORPE & S. RANG (1986) – Association of wetland acidity with reproductive parameters and insect prey of the eastern kingbird (*Tyrannus tyrannus*) near Sudbury, Ontario. *Water Air Soil Pollution*, **30**: 553-567.

6. ORMEROD, S.J., K.R. BULL, C.P. CUMMINS, S.J. TYLER & J.A. VICKERY (1988) – Egg mass and shell thickness in Dippers (*Cinclus cinclus*) in relation to stream acidity in Wales and Scotland. *Environ. Pollution*, **55**: 107-121.

7. GRAVELAND, J. (1990) – Effects of acid precipitation on reproduction in birds. *Experientia*, **46**: 962-970.

8. SCHMIDT, K.-H. (1990) – Sprunghafter Anstieg von Brutstörungen bei Höhlenbrütern. *J. Orn.*, **131**: 172-174.

9. CARLSSON, H., L. CARLSSON, C. WALLIN & N.-E. WALLIN (1991) – Great tits incubating empty nest cups. *Ornis Svecica*, **1**: 51-53.

10. GRAVELAND, J. & T. VAN GIJZEN (1994) – Arthropods and seeds are not sufficient as calcium sources for shell formation and skeletal growth in passerines. *Ardea*, **82**: 299-314.

11. GRAVELAND, J. (1996) – Eggshell defects in forest passerines caused by decline of snail abundance on acidified soils. *Vogelwelt*, **117**: 67-73.

12. JONES, P.J. (1976) – The utilization of calcareous grit by laying *Quelea quelea. Ibis*, **118**: 575-576.

13. TURNER, A.K. (1982) – Timing of laying by swallows (*Hirundo rustica*) and sand martins (*Riparia riparia*). *J. Anim. Ecol.,* **51**: 29-46.

14. SOKAL, R.R. & F.J. ROHLF (1981) – *Biometry*, 2nd edn. New York: W.H. Freeman.

15. DRENT, P.J. & J.W. WOLDENDORP (1989) – Acid rain and eggshellls. *Nature*, **339**: 431

16. BITMAN, J., H.C. HARRIIS & G.F. FRIES (1969) – DDT induces a decrease in eggshell calcium. *Nature*, **224**: 44-46.

17. RATCLIFFE, D.A. (1970) – Changes attributable to pesticides in egg breakage frequency and egg shell thickness in some British birds. *J. Appl. Ecol.*, **7**: 67-115.

18. NEWTON, I. (1979) – *Population Ecology of Raptors*. Collins, London.

19. OPDAM, P., J. BURGERS & G. MUSKENS (1987) – Population trend, reproduction and pesticides in Dutch sparrowhawks following the ban on DDT. *Ardea*, **75**: 205-212.

20. VANDEGEHUCHTE, M. (1989) – Zwarte stern, *Chlidonias niger. In : Vogels in Vlaanderen: voorkomen en verspreiding.* Vlaamse Avifauna Commissie. Bornem.

21. MAES ,P. & H. VOET (1988) – Zwarte stern, *Chlidonias niger. In:* Devillers, P., Roggeman, W., Tricot, J., del Marmol, C., Kerwijn, C., Jacob, J.-P. & Anselin, A. (eds.). *Atlas van de Belgische broedvogels. Brussel, Koninklijk Belgisch Instituut voor Natuurwetenschappen.*

22. BEINTEMA, A.J., T. BAARSPUL & J.P. DE KRIJGER (1997) – Calcium deficiency in Black Terns *Chlidonias niger* nesting on acid bogs. *Ibis*, **139**: 396-397.

Received : 3 June 1997