J. Ornithol. 139, 307–312 (1998)

ISSN 0021-8375

Effects of fertilizer-induced reduction of invertebrates on reproductive success of Loggerhead Shrikes *(Lanius ludovicianus)*

Reuven Yosef[1,2] and Mark A. Deyrup[1]

[1]Archbold Biological Station, P. O. Box 2057, Lake Placid, FL 33852, USA; [2]Current address: International Birding Center in Eilat, Dept. of Life Sciences, Ben-Gurion Univ. of the Negev, P. O. Box 774, Eilat 88000, Israel (e-mail: ryosef@BGUMAIL.BGU.AC.IL)

Summary

We examined the effect of spraying the common fertilizer, sodium ammonium nitrate, on cattle pastures in central Florida. Shrikes are considered good indicators of habitat quality. Hence, eight pairs of shrikes whose territories were sprayed were considered as the treatment group, and four pairs in unsprayed territories as controls. The fertilizer was sprayed on 18 June 1992, when the resident shrikes were into their second and third nests, and within 24 h the dominant bahia grass and patches of blackberry bushes became chlorotic. The eight treatment pairs expanded their territories significantly by 138.5% on average, and the smaller their initial territory, the greater the change. The total number of insects collected in the sprayed pasture in the first three weeks was extremely low compared to the number in the unsprayed pasture. In the control pairs no loss of eggs, young, or adults owing to abiotic causes was observed. However, in the treatment pairs seven eggs, two nestlings, and eight fledglings disappeared, or died from causes attributed to the spraying. In addition, seven females and one male disappeared, and one territory was abandoned. Our observations suggest the need for additional studies to examine the effects of supposedly "environmentally friendly" fertilizers and show the value of monitoring breeding bird populations in agricultural systems.

Key words: agriculture, ammonium nitrate, monitoring, pastures, population

Zusammenfassung

Düngerausbringung reduziert Nahrungsangebot und beeinträchtigt den Bruterfolg des Louisianawürgers *(Lanius ludovicianus)*

Die Auswirkungen der Ausbringung eines in den USA weithin gebräuchlichen Kalium-Ammonium-Nitrat-Düngers auf Viehweiden wurde an Louisianawürgern im Vergleich von acht betroffenen und vier nichtbetroffenen Paaren geprüft. Würger gelten allgemein als gute Indikatoren für Habitatqualität. Der Dünger wurde am 18. Juni 1992 ausgebracht, als die Würger mitten in ihrem Brutgeschäft waren. Bereits innerhalb eines Tages war die Vegetation stark geschädigt. Die von der Sprühung betroffenen Würger vergrößerten ihre Reviere um 138.5%, wobei Vögel mit vormals kleinen Revieren ihre Territorien besonders vergrößerten. Die Anzahl während der ersten drei Wochen nach der Ausbringung gesammelter Insekten war auf den besprühten Flächen im Vergleich zu den unbehandelten Weiden sehr gering. Während in von der Sprühung nicht betroffenen Bruten keinerlei auf abiotische Umstände zurückgehende Verluste an Eiern, Jungvögeln oder Altvögeln festzustellen waren, traten bei den Bruten auf den besprühten Flächen erhebliche Verluste auf. Neben dem Verlust an sieben Eiern, zwei Nestlingen und acht gerade flüggen Vögeln, verschwanden auch sieben Weibchen und ein Männchen, und ein Revier wurde verlassen. Die Beobachtungen verdeutlichen die Notwendigkeit, auch sog. „umweltverträgliche" Düngemittel auf ihre Wirkungen zu testen, und sie zeigen zugleich den Wert eines Umweltmonitorings mit Vögeln in der Agrarlandschaft.

Introduction

Shrikes (*Lanius* spp.) inhabit ecotones and are exposed to environmental and ecological fluctuations and instabilities (Morrison 1981). Their populations react quickly to the changing environment, and numerical changes can be detected easily and measured reliably. Owing to their

conspicuousness and the types of open habitats they use, shrikes are reliable bioindicators, and hence a monitoring program based on shrikes is likely to prove useful in detecting environmental changes (Safriel 1995).

Annual use of artificial fertilizers has increased greatly during the past two decades, with probable continued heavy use for production of farm crops and pasture habitats. The effects on wildlife habitat from fertilizer application are not well known. It is assumed that fertilizers certified for use by federal agencies are safe. We examined the effects of spraying a widely-accepted fertilizer on pastures where pairs of Loggerhead Shrikes had established territories.

This was not a planned experiment because the spraying of the pastures on 18 June 1992 was unexpected by the authors. Data were collected immediately upon discovery of the spraying from shrike territories that had been previously mapped and that had active nests. The eight pairs whose territories were sprayed were considered the treatment group, and the four pairs with unsprayed territories as the control group. We postulated that the spraying of a semi-natural environment would adversely affect the existing fauna and used the nesting shrikes to test this prediction.

Study area and methods

This study was conducted at the MacArthur Agroecology Research Center (480000E, 3004000 N UTM; 11 m ASL), a 4,200-ha cattle ranch of the Archbold Biological Station, Florida. The site, nearly equidistant from the Atlantic and Gulf coasts of Florida, consists of pastures of improved bahia grass *(Paspalum notatum)*, cabbage palm *(Sabal palmetto)* hammocks, native wetlands, and live oak *(Quercus virginianus)* uplands.

Territorial shrikes were captured in baited noose traps and ringed with U. S. Fish and Wildlife Service aluminum bands and color rings. During the course of a previous study (January 1990 – June 1993), Yosef (1992) used the shrikes' aggressive responses to playbacks and taxidermic mounts to map the borders of all territories on the ranch (Gawlik 1988). Territory size was calculated as the minimum polygon bounded by defended points of the habitat. Data on number of clutches, eggs per clutch, and number of young fledged were collected from 23 monogamous pairs of shrikes. A nest was considered successful if at least one young fledged. Unless otherwise indicated, data are given as means ± s.d. We chose $p = 0.05$ as the minimum acceptable level of significance.

The fertilizer, applied at the rate of 54 kg/ha in our study area, is widely used by most cattle ranchers in North America and is commonly called 19-0-0. It is a liquid spray of sodium ammonium nitrate and contains 19.00% nitrogen (nitrate nitrogen 10.83%, ammoniacal nitrogen 8.17%; $NH_4NO_3 + CO(NH_2)_2 + H_2O$) and 1.00% chlorine. Material Safety Data Sheets (MSDS 1989) state that the U. S. Department of Labor, Occupational Safety and Health Administration requirements have established that no hazardous ingredients are included, but spray operators are required to wear protective safety gear (chemical splash goggles, rubber gloves, suitable clothing). No data on the toxicity of this fertilizer were found in the existing literature.

We first discovered that the fertilizer had been sprayed on 19 June 1992. Because of our knowledge of all local shrike territories during two years (Yosef 1992), we were in a position to identify a change in the positions of the adults in territories where their hunting substrate was sprayed. We also noted that the nesting season terminated earlier than usual for pairs whose territories were sprayed. Pairs in an equivalent reproductive stage (i.e., "control" territories) did not appear to have changed in their behaviour. To understand this alteration of behaviour, we measured change in territory size, sweep-sampled for insects in one sprayed territory and one unsprayed territory, and observed loss of nests, young, and adults in the sprayed territories. Neighboring territories were chosen for sweep-sampling with hand-nets in order to evaluate the effect of the fertilizer on the entomofauna. In each field eight replicates of 30 two-way sweeps were made once a week for the three weeks following the spraying, i.e. on 23 June, 30 June, and 14 July 1992 (Table 2). All known nests were checked to verify the fate of each of the eggs or young (Table 1). At each visit we attempted to ascertain the presence of both parents. Adults not seen for three consecutive visits were considered to have deserted or died. We also evaluated the effect of the release of a herd of cattle into a recently fertilizer-sprayed pasture.

Results

The spraying of the fertilizer was obvious on the bahia grass of the pastures and blackberry bushes *(Rubus betulifolius)*, because within 24 h the plants became chlorotic (yellowish, wilted foliage, and sickly).

Effects on territory size

All 12 shrike territories were mapped by 1 July and compared to the established boundaries mapped during February and March 1992. The four control territories had decreased in area ($\chi^2 = 0.01$, $p = 0.99$), on average by 0.9% ± 2.1 s.d. (range −3.8 to +1.2%; Table 1). However, the eight treatment territories had increased in area significantly ($\chi^2 = 12.55$, $p = 0.05$), by an average of 138.5% ± 86.1 (range +135.3 to +343.5%). A significant ($\chi^2 = 861.38$, $p = 0.0001$) difference occurred between the changes in territories of the control and treatment groups following the spraying. Moreover the smaller the territory, the greater was the change ($r^2 = 0.727$, 7 df, $p = 0.015$, Fig. 1). In

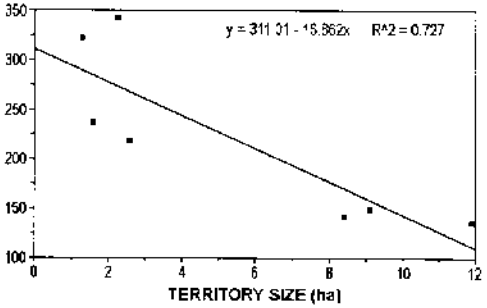

Fig. 1. Percent change in territory size of Loggerhead Shrikes following the spraying of the fertilizer 19-0-0.

Abb. 1. Veränderungen der Reviergröße bei Louisianawürgern nach der Ausbringung des Düngers 19-0-0.

Table 1. Effects of spraying fertilizer on territory size (ha), survival of eggs, young, and adults of eight pairs of Loggerhead Shrike compared with four pairs that were not sprayed (* denotes excluded from calculation of average).

Tab. 1. Reviergröße (ha) und Überlebensrate der Nestlinge und Altvögel bei 8 Paaren des Louisianawürgers, die von der Düngerausbringung betroffen waren (treatment) im Vergleich zu vier Paaren, die nicht betroffen wurden (controls). * Beim Mittelwert nicht berücksichtigt.

	Controls			Treatment		
	Before	After	% Change	Before	After	% Change
	2.0	2.0	0.0	1.3	4.2	+323.1
	5.2	5.0	−3.8	1.6	3.8	+237.5
	8.5	8.6	+1.2	2.3	7.9	+343.5
	9.0	8.9	−1.1	2.6	5.7	+219.2
				8.4	11.9	+141.7
				9.1	13.6	+149.5
				11.9	16.1	+135.3
				14.5	abandoned*	
Average	6.2	6.2	−0.9	6.5	9.0	+138.5
s.d.	3.3	3.3	2.1	5.2	4.9	86.1
N	4	4	4	8	7	7

Control (unsprayed) Group		
1	Not sprayed	2 adults unaffected, 4 young fledged
2	Not sprayed	2 adults unaffected, 2 young fledged
3	Not sprayed	2 adults unaffected, 2 young fledged
4	Not sprayed	2 adults unaffected, 2 young fledged
Treatment (sprayed) Group		
5	Pasture	Female and 2 fledglings disappeared
6	Pasture	Female and 2 fledglings disappeared
7	Pasture, nest bush	Both parents & 4 young disappeared Territory abandoned
8	Pasture, nest bush	Female and 2 fledglings disappeared
9	Pasture, nest bush	Clutch of 3 eggs sprayed
10	Pasture, nest bush	Female disappeared, 2 nestlings dead
11	Pasture, nest bush	Female and 2 fledglings disappeared
12	Pasture, nest bush	Female disappeared, 4 eggs sprayed

addition, the nesting season was terminated significantly earlier than usual for pairs whose territories were sprayed (18 June compared to 7, 16, 22, and 22 July; $\chi^2 = 17.29$, 3 df, $p = 0.0006$).

Effects on entomofauna

The total number of insects collected in the sprayed pasture two weeks after the fertilizer was applied was lower than in the unsprayed pasture (Table 2). This was further substantiated by the total number of species caught. Based on our samples, we assume that 13 to 14 species were normally found during that period of year in the top strata of the bahia grass where shrikes normally forage. During the first two weeks after spraying, the number of species collected was about 60% below this level.

During the 1990 and 1991 breeding seasons shrikes bred from January till July. The eight pairs whose territories were sprayed did not renest. At the time of spraying, eight females, eight males, two clutches totalling seven eggs, one brood of two nestlings, and five broods totalling 17 fledglings were present. Of these, seven eggs (100%), two nestlings (100%), and eight fledglings (47%) disappeared or died. In addition, seven females (87.5%) and one male (12.5%) disappeared, and one territory was abandoned. For the control sites, no eggs, young, or adults were lost during this study. Mammalian and reptilian predation accounted for only two unsprayed nests that did not fledge young.

Discussion

The results suggest that spraying of a synthetic

Table 2. Effect of spraying of fertilizer on 18 June 1992 on the insect fauna of a pasture. Values represent the number of insects caught in 100 sweeps along a 50m transect. "s" denotes sprayed pasture and "us" unsprayed pasture.

Tab. 2. Einfluß der Sprühaktion am 18. Juni 1992 auf die Insektenfauna. Die Zahlen beziehen sich auf die Anzahl Insekten in 100 Kescherzügen entlang eines 50 m-Transektes. S = besprüht; US = nicht besprüht.

Species	23 June		30 June		14 July	
	S	US	S	US	S	US
Tettigoniidae	5	41	3	31	3	13
Acrididae	1	5	0	17	1	3
Dermaptera	0	3	0	2	0	1
Mantidae	0	8	0	3	0	1
Gryllidae	0	2	0	4	0	1
Pentatomidae	0	1	4	4	2	3
Elateridae	0	1	0	1	0	0
Chrysomelidae	0	5	0	8	1	3
Pyralidae (adult)	4	6	1	1	0	0
Lepidoptera (larva)	1	3	0	1	0	0
(adult)	0	0	0	0	1	4
Zygoptera (adult)	1	3	0	1	0	0
Pompilidae	0	1	0	0	0	0
Alydidae	0	1	0	0	0	0
Tiphiidae	0	0	0	1	0	0
Libellulidae	0	0	0	1	0	0
Syrphidae	0	0	2	3	4	5
Sarcophagidae	0	0	0	0	6	119
Hesperiidae	0	0	0	0	2	0
Odonata	0	0	0	0	3	5
Nabidae	0	0	0	0	1	0
Coccinellidae	0	0	0	0	0	3
Tabanidae	0	0	0	0	0	1
Ichneumonidae	0	0	0	0	0	1
Total number of insects	12	80	10	78	24	163
Total number of species	5	13	4	14	10	14

fertilizer on a semi-natural environment adversely affected the fauna. The spraying of the pastures stunted the bahia grass and defoliated the blackberry bushes. This decreased the prey base, and consequently negatively affected the reproduction and survival of Loggerhead Shrikes in the area.

The depleted insect populations formed the prey base of various food chains, and are eaten by Loggerhead Shrikes (Yosef 1996). Their depletion must have disrupted the feeding practices of the various predators. We infer that the increase in the total area defended by shrikes occurred to gain access to a necessary minimum of prey. Yosef (1992) and Yosef and Grubb (1994) considered hunting perch-sites to be the primary limiting factor of territory size in Loggerhead Shrikes; however, the results of this study indicate that territory size is also influenced by the prey density (Bent 1950). This is especially important to validate because the Loggerhead Shrike is one of the few species that in recent decades have experienced a continent-wide decline in the Breeding Bird Surveys (Robbins et al. 1986, Peterjohn and Sauer 1993).

Another indication of the loss of the food base was the disappearance of breeding adults and death of chicks. Further, the desertion of the largest territory sprayed indicates that the pair was faced with the choice of increasing its territory to a point that made it energetically uneconomical or of abandoning it. This territory was still vacant up to 12 months after spraying. The desertion by only females in the other territories shows up our lack of knowledge of the social structure of this predatory species. Yosef and Pinshow (1989) found that male Northern Shrikes *(L. excubitor)* in Israel reside in and defend territories all the year round, while females are not permanent residents and leave immediately after the broods fledge. Thus, it is possible that in resident populations of the Loggerhead Shrike of North America females are less faithful to their territories than are males.

Cattlemen consider patches of blackberry bushes in pastures as unwanted and sprayers specifically target them. These randomly growing bushes in the midst of the pastures are also important, and are safer, nesting sites for many avian species than are those in fencelines and hedgerows (Yosef 1994).

In conclusion, this study illustrates that fertilizer sprays, although federally certified for use, may have negative side-effects. History has shown that many of the chemicals used in agriculture are harmful to a greater degree than at first estimated. If we wish to conserve the remaining biodiversity to the maximum feasible extent, we have to be constantly on guard to detect deleterious effects of the contaminants that are continually being added to the environment in the cause of making life better for humans. Our observations and data suggest a need for additional studies to examine the validity of the supposedly benign and "environmentally friendly" fertilizers and show the value of monitoring breeding bird populations in agricultural systems.

Photographic documentation in the form of slides is available either from the author or the photographic archives of the Archbold Biological Station.

Acknowledgements

RY received a conservation grant from the American Ornithologists' Union and a research grant from the Animal Behavior Society during this study. Brad Stith, Steve Friedman, Walter Meshaka, and Sarah Childs gave technical help. I. Lehr Brisbin, Jr., Tom Cade, Chandler S. Robbins, and two anonymous reviewers commented on an earlier draft of this paper. This is contribution 38 of the MacArthur Agro-ecology Research Center, Archbold Biological Station.

References

Bent, A.C. (1950): Life histories of North American wagtails, shrikes, vireos and their allies. U. S. Nat. Mus. Bull. 197.

Gawlik, D. (1988): Taped shrike call and decoy as possible lures for trapping Loggerhead Shrikes. N. Am. Bird Bander 13: 123.

Morrison, M.L. (1981): Population trends of the Loggerhead Shrike in the United States. Am. Birds 55: 754-757.

Peterjohn, B.G. & Sauer, J.R. (1993): North American Breeding Bird Survey annual summary 1990-1991. Bird Populations 1: 1-15.

Robbins, C.S., Bystrak, D. & Geissler, P.H. (1986): The Breeding Bird Survey: its first fifteen years, 1965-1979. U.S. Fish Wildl. Serv. Resour. Publ. 157.

Safriel, U. N. (1995): What's special about shrikes?

Conclusions and recommendations. In: Yosef, R. & Lohrer, F.E.; eds.): Shrikes of the world: biology and conservation: 299-308. Proc. Western Foundation of Vert. Zool. 6 (1).

Yosef, R. (1992): Territoriality, nutritional condition, and conservation in Loggerhead Shrikes. Ph.D. diss., The Ohio State Univ., Columbus, OH.

Yosef, R. (1994): The effects of fencelines on the reproductive success of Loggerhead Shrikes. Conserv. Biol. 8: 1-5.

Yosef, R. (1996): Loggerhead Shrike *(Lanius ludovicianus)*. In: Poole, A., Stettenheim, P. & Gill, F., eds.): The Birds of North America No. 231, Washington D.C.

Yosef, R. & Grubb, T.C., Jr. (1994): Resource dependence and territory size in Loggerhead Shrikes *(Lanius ludovicianus)*. Auk 111: 465-469.

Yosef, R. & Pinshow, B. (1989): Cache size in shrikes influences female mate choice and reproductive success. Auk 106: 418-421.

Accepted: 18 February 1998