

EFFECT OF HABITAT QUALITY ON THE HUNTING BEHAVIOUR OF BREEDING GREAT GREY SHRIKES (*LANIUS EXCUBITOR*)

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Hunting behaviour and use of different habitat types of a breeding Great Grey Shrike family was observed in a recycled landfill near Eilat, Israel. As Great Grey Shrikes were not observed to breed in the Eilat area for more than a decade, detailed observations of hunting site selection were conducted. Additionally, arthropod abundance and impaled prey items were monitored. The breeding pair established its territory on the boundary of the "Bird Sanctuary", a former recycled landfill, where irrigation has facilitated the growth of dense vegetation inside the park boundary, while outside of it the sparse vegetation characteristic of semideserts is found. Huntings were categorised as either inside or outside of the Bird Sanctuary. While water traps were applied to measure insect availability inside and outside the Bird Sanctuary. We found that the shrikes foraged preferentially within the Bird Sanctuary (Paired t-test, $N=122$, t-value: 3.63, $P < 0.005$). Diversity (revealed by Rényi diversity index) and abundance of arthropods were considerably higher inside the Bird Sanctuary (Wilcoxon Matched pairs Signed-ranks test, z-value > -2.428 , $P = 0.0152$). The monitoring of impaled prey items revealed that besides insects vertebrates were also taken. Interestingly two specimens of the poisonous Black Cone-headed Grasshopper (*Poikilocerus bufonicus*) were also impaled and consumed.

Key words: Great-Grey Shrike, *Lanius excubitor*, habitat-choice, prey-availability, impaling

INTRODUCTION

Shrikes (Family Laniidae) are prominent birds of open habitats and are important as indicator species of environmental degradation because they are predatory and closely associated with agricultural areas (HANDS *et al.* 1989, SAFRIEL 1995). Shrikes are at present of special concern because many of the 30 species are declining, or have become locally extinct (TUCKER *et al.* 1994, YOSEF 1994). Most long-term studies of previously robust populations of shrikes have documented drastic declines, mostly in the late 20th century (e.g., BUSSE 1995, PEAKALL 1995, PETERJOHN & SAUER 1995).

Several factors have been suggested as causes for shrike population declines, but changes in human land-use practices may be the most likely explanation (e.g., Great Grey Shrike, *Lanius excubitor*, in Switzerland – BASSIN 1981; Red-backed

Shrike, *L. collurio*, in Sweden – OLSSON 1995; Loggerhead Shrike, *L. ludoviciana*, in North America – DROEGE & SAUER 1990; Brown Shrike, *L. cristatus*, in Japan – HAAS & OGAWA 1995). Other explanations range from climate change, i.e., wetter, cooler summers, which reduce activity and abundance of invertebrates (DURANGO 1950, PEAKALL 1962, LEFRANC 1993), to heavy application of inorganic nitrogen fertilisers causing vegetation to grow early, dense and high (ELLENBERG 1986, MARECHAL 1993).

The Great Grey Shrike is extremely widely distributed in the Holarctic region (PANOW 1996), and its breeding area stretches from the North of Europe down to Israel and Northern Africa. The Great Grey Shrike was a common breeding species in the Eilat region (YOSEF 1998) and was extirpated because of rural and housing development and use of biochemicals in the surrounding agricultural fields. Thus, the fact that after a lapse of almost ten years a pair of Great Grey Shrikes established a breeding territory on an area recycled from a garbage dump into a "Bird Sanctuary" by the International Birding and Research Center in Eilat (IBRCE) suggested that the area had become a sustainable habitat for this indicator species.

Optimal foraging theory and the marginal value theorem are widely applied to test how organisms choose feeding sites and prey types based on their profitability (CHARNOV 1976). This predicts that an organism should forage in a patch only so long as the average food intake in this patch is higher than in all other surrounding patches. The combination of prey and patch models (STEPHENS & KREBS 1986) further predicts that patches of highest intake rates are preferred by birds when the size of patches guarantees that their depletion is impossible. In order to test whether Great Grey Shrikes forage optimally we wished to establish whether the birds were able to select foraging sites with higher food availability, and hence higher profitability. We hypothesised that wild Great Grey Shrikes are capable of evaluating the productivity of neighbouring habitats and predicted that the studied birds would spend a relatively greater period of time hunting in the habitat that had greater prey abundance, and was thus energetically more profitable. This study also allowed us to evaluate the success of the experiment wherein we created the "Bird Sanctuary" on top of a landfill, in relation to its surrounding areas. We further hypothesised that owing to the irrigation and higher density of plants in the boundaries of the "Bird Sanctuary," we would find a greater density of entomofauna within the boundaries of the Bird Sanctuary in relation to the surrounding areas.

MATERIALS AND METHODS

The International Birding and Research Center in Eilat (IBRCE), out of concern for the welfare of staging migratory bird populations of Eurasia in the Eilat region, initiated the study of the ef-

fects of human land-use changes on avian migrants. To this effect the IBRCE was allocated a 50 ha landfill as a 'land recycling' experiment. The landfill was in use from the early 1950's till the mid 1970's and was the major landfill for the region. This offered us a unique chance to recycle a 'human abused' landscape and to make it environmentally friendly i.e., to convert it into a 'bird sanctuary'. The ultimate goal is to create a sanctuary for migrant species in the fast growing human-built concrete jungle by planting species that fruit or flower during migration seasons. In addition, the municipality and the Mekorot water works allow the use of partially treated sewage water for irrigating the trees and creating a fresh water lake on the site. The irrigation water is extremely rich in organic matter and has allowed the trees an extremely fast growth and flowering rate, and a higher than normal seed production rate.

During spring 1997 a pair of Great Grey Shrikes established a breeding territory on the western boundary of the bird sanctuary (29°33'N, 34°57'E) and built a nest in an *Acacia radiata* tree. Visits of the parents were monitored for 10 consecutive days, between 30th March and 14th April 1997, for a total of 22 hours. Foraging site of the parents was categorised as either inside or outside the boundaries of the "Bird Sanctuary".

To compare the prey available to shrikes within and outside the bird sanctuary, insect transects and arthropod trapping was conducted in these areas. The length of each invertebrate transect was 50 metres. We recorded all invertebrate seen on the ground or on the vegetation within a 1 m radius of the path (50 x 2 metres). Two transects were conducted, one inside the "bird sanctuary," and one 40 m parallel to the western boundary. The procedure was repeated at an additional locality within and outside the "bird sanctuary." All transects were conducted on 28th April 1997.

The arthropod fauna composition of the habitats was evaluated with the use of white-water traps (HARPER & STORY 1962, SOUTHWOOD 1966). Sixteen (eight in each habitat) white plastic trays of 20.5 cm diameter, filled with 2 cm of water and 2-3 drops of detergent, were placed in the study areas and were emptied after 24 hours. The two trapping sessions were conducted on 22nd and 28th April 1997.

To analyse the white-water trap data we calculated Shannon-Wiener diversity, evenness and Margalef richness indices (PIELOU 1975). Wilcoxon matched-pairs signed-ranks tests (ZAR 1996) were applied to compare the abundance of specimens in each captured invertebrate orders in a pair-wise manner. Diversity ordering, based on the Rényi formula, was also performed for comparison of species richness (TÓTHMÉRÉSZ 1995, 1997). The Rényi diversity index family is well-known for providing reliable results for communities of all sizes (TÓTHMÉRÉSZ 1995). The NuCoSa 1.0 and DivOrd software packages (TÓTHMÉRÉSZ 1993, 1996, 1997) were applied to conduct the calculation of diversity ordering. SPSS PC (NOURIS) and Statistica programme packages were applied to carry out the tests.

RESULTS

A total of 150 foraging sessions were observed. Of these the majority (103 vs 47) were within the boundary of the "Bird Sanctuary" (Fig. 1) and was significantly higher than the number of forages outside (Wilcoxon Matched-pairs Signed-ranks test, 2-tailed, $Z = -2.5992$, $P < 0.0093$).

The total number of invertebrates counted on transects (27 vs 5; Table 1) and collected in the white-water traps (Table 2) was greater inside the bird sanctuary. Both during the first and second trapping the number of invertebrates caught was

Table 1. Entomofauna observed on invertebrate transects within the "Bird Sanctuary" and outside its boundaries

Species	Outside bird sanctuary	Inside bird sanctuary
Lepidoptera sp.	0	6
Diptera sp.	0	18
Formicidae sp.	5	1
Orthoptera sp.	0	1
Heteroptera sp.	0	1
Total	5	27

considerably higher inside the Bird Sanctuary. The pairwise comparison of number of arthropods in each order proved that abundance is significantly higher inside the Bird Sanctuary (Wilcoxon Matched-pairs Signed-ranks test, 2-tailed, first session: $Z = -2.4286$, $P = 0.0152$, second session: $Z = -2.5205$, $P = 0.0117$)

For the first trapping Rényi diversity index was constantly higher for the traps inside the bird sanctuary than on the outside (Fig. 2A). However, for the second trapping session (Fig. 2B) the two lines intersect such that diversity cannot be ranked. The overall result is that abundance of trapped invertebrates is considerably higher inside the bird sanctuary.

The size distribution of the invertebrates trapped outside and inside the Bird Sanctuary also differed considerably. From the total of 196 insects trapped inside the Bird Sanctuary, 57 (29.1%) were larger than 3 mm and 139 (70.9%) were

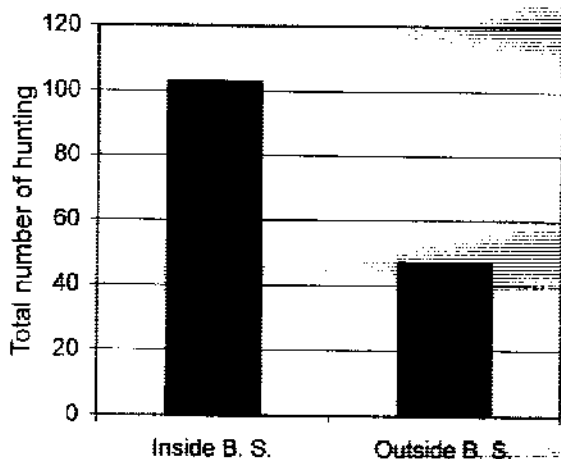


Fig. 1. Proportion of hunting attempts outside and inside the boundaries of the Bird Sanctuary by Great Grey Shrikes. Inside B.S denotes hunting within the boundaries of the Bird Sanctuary; Outside B.S. denotes hunting outside the boundaries of the Bird Sanctuary

smaller than 3 mm. In contrast, outside the Bird Sanctuary from a total of 43 invertebrates, 39 (90.7%) were smaller than 3 mm and only 4 (9.3%) were larger than 3 mm. These proportions of large and small insects were significantly different between the Bird Sanctuary and adjacent areas (χ^2 -square test, $df=1$, $\chi^2=6.25$, $P=0.0124$ after Yates correction).

DISCUSSION

The recycling of a landfill into a bird sanctuary to serve as a staging area for migratory birds is a concept that is not wide-spread. The critical location of Eilat on the eastern flyway of the Palaearctic, and the extensive human development in the region in recent decades, requires such conservation measures to succeed to ensure the continued survival of the Eurasian bird populations. The best possible measure for success is that of the wildlife returning to areas previously abandoned by the species. Unfortunately, the decline or disappearances of bird species from areas where human activities alter habitats are more abundant.

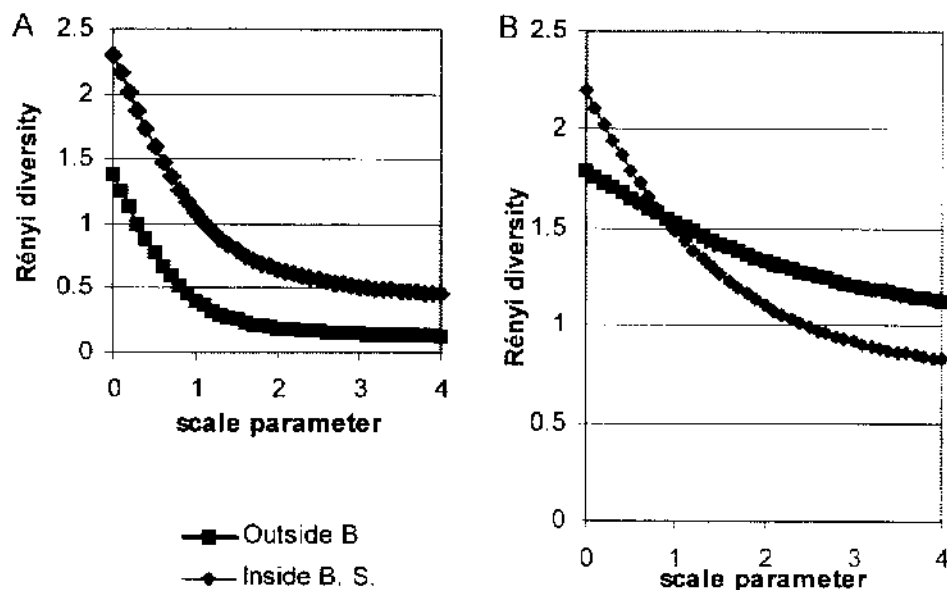


Fig. 2. Rényi diversity ordering for the arthropods caught during the first trapping (A) and second trapping (B). Inside B.S. denotes within the boundaries of the Bird Sanctuary; Outside B.S. denotes outside the boundaries of the Bird Sanctuary

Table 2. Results of two sessions of invertebrate trapping using white-water traps inside and outside the boundaries of the "Bird Sanctuary" in Eilat, Israel

Species	21 April		28 April	
	Outside	Inside	Outside	Inside
Hymenoptera	0	15	2	22
Diptera	0	7	14	15
Formicidae	0	22	6	28
Orthoptera	0	1	0	1
Heteroptera	2	1	0	1
Arachnidae	0	3	0	5
Homoptera	0	1	8	16
Coleoptera	1	6	6	6
Lepidoptera	1	1		
Others	39	139	26	109
Total	43	196	62	203
	Diversity			
Shannon index	0.41	1.08	1.52	1.48
	Richness			
Margalef	0.80	1.71	1.21	1.5
Menhinick	0.61	0.71	0.76	0.63

The breeding attempt by the pair of Great Grey Shrikes after an absence of more than a decade in the region is just such an indication. Further, the greater hunting effort calculated for unit observation time was higher in the irrigated area, as was the number of large insects that are suitable for Great Grey Shrikes as prey items. Prey availability is a good predictor of avian foraging decisions, as has previously been proved especially in shrikes (MILLS 1979, YOSEF & GRUBB 1993, 1994). We should also mention that the vegetation inside the Bird Sanctuary provided ample perch-sites, and its importance is highlighted by MOSKÁT *et al.* (2000).

Optimal foraging theory predicts that birds will choose feeding patches, where the average intake rate is the highest, and leave the foraging sites as profitability of other sites is greater due to depletion of prey (SCHOENER 1971, CHARNOV 1973, 1976, PYKE *et al.* 1977). But in reality, large stretches of a given patch, i.e., large areas covered by the same vegetation type, might provide insects or other resources in such quantities that foraging birds can not practically deplete them. STEPHENS and KREBS (1986) formulated a habitat selection prediction for such instances from the patch model and predicted that birds should choose those habitats that provide the highest food intake. For the foraging shrikes different

types of agricultural lands constitute just such habitats (YOSEF & LOHRER 1995, 1998). The study of foraging Loggerhead Shrikes in Florida, U.S.A. (YOSEF & GRUBB 1993) and Red-backed Shrikes (FUISZ 2002) in Hungary, in a habitat, where uncut and cut grass yielded feeding sites with different prey availability showed that more hunting trips were conducted in the patches with uncut grass. The analysis of prey availability in the cut and uncut patches revealed that both the number of large insects and diversity of invertebrates is higher in the patches of uncut grass. Similarly in the case of the Great Grey Shrikes the different types of vegetation inside and outside the boundaries of the Bird Sanctuary maintain different invertebrate communities. The importance of surface dwelling insects in the diet of breeding shrikes was emphasised by several authors (e.g., WAGNER 1994, HROMADA & KRISTIN 1996, SCHÖNN 1995). Both invertebrate-census transects and white-water trapping revealed that abundance of invertebrates was significantly greater inside the recycled landfill and at-present irrigated area. In addition, as the majority of the foraging trips were concentrated inside the Bird Sanctuary, this suggests that the Great Grey Shrike pair foraged optimally, and preferentially, in the given habitat. WHITEHEAD and WRIGHT (1994) also showed that foraging starlings (*Sturnus vulgaris*) choose meadows that offer a higher food intake.

In our observations in the field, however, we also saw the shrikes hunt actively outside the boundaries of the Bird Sanctuary, in the sparse vegetation. The monitoring of impaled prey revealed that, although during our observations predominantly invertebrate prey were brought to the nest (on one occasion a lizard), the impaled caches consisted predominantly of birds, namely the resident House Sparrow (*P. domesticus*) and migratory Spanish Sparrow (*Passer hispaniolensis*) and Blackcap (*Sylvia atricapilla*). On the mature Accacia trees outside the Bird Sanctuary large flocks of migratory passerine species were frequently observed and appear to be another food source for the breeding shrikes. TYRJANOWSKY *et al.* (1999) also showed in Poland that breeding Great Grey Shrikes preferred and successfully utilised breeding sites containing two different basic habitat types: in the spring crops they hunted for insects and in the adjacent rural meadows they mainly caught vertebrate prey items.

Only two invertebrate specimens were found impaled during our study. Interestingly both were the highly poisonous Black Cone-headed Grasshopper (*Poikilocerus bifonicus*). One of these was consumed three days after impaling and is in contrast to the other impaled vertebrates that were fed to the brood within 24 hours of impaling. The longer period of time probably allowed for detoxification and subsequent consumption of an otherwise unpalatable prey. This has previously been shown to occur in the Loggerhead Shrike (*L. ludovicianus*) that is able to overcome the toxic defenses of a wide range of chemically defended invertebrates,

including lubber grasshopper (*Romalea guttata*), the moth *Utetheisa ornatrix*, and the beetle *Lytta polita*, after "curing" them by impaling for extended periods of time (YOSEF & WHITMAN 1992, YOSEF *et al.* 1996).

All of the above factors combined give a picture of success for the recycled landfill and wherein the environment is in a better balance than the surrounding agricultural or urban areas. Our results support the hypotheses that indeed the Bird Sanctuary has a greater density of entomofauna within the boundaries of the Bird Sanctuary in relation to the surrounding areas, and that Great Grey Shrikes were capable of evaluating the productivity of neighbouring habitats. And consequently the study birds spent a relatively greater period of time hunting in the habitat that had greater prey abundance, and was thus energetically more profitable.

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REFERENCES

- BASSIN, P. (1981) Répartition et biotopes de la Pie-grèche grise, *Lanius excubitor*, dans le nord-ouest de la Suisse (Ajoie, canton du Jura). *Nos Oiseaux* 36: 1–20.
- CHARNOV, E. L. (1973) *Optimal foraging: some theoretical explorations*. Ph.D. diss., Univ. Washington, Seattle.
- CHARNOV, E. L. (1976) Optimal foraging: the marginal value theorem. *Theor. Popul. Biol.* 9: 129–136.
- DROEGE, S. & SAUER, J. R. (1990) North American Breeding Bird Survey annual summary, 1989. *U.S. Fish Wildl. Serv. Biol. Rep.* 90: 1–22.
- DURANGO, S. (1950) Om klimatets inverkan på tornskattans (*Lanius collurio* L.) utbredning och levnadsmöjligheter. *Fauna Flora* 45: 49–78.
- DVORAK, M. & ZUNA-KRATHY, T. (1993) Zur aktuellen Situation ausgewählter Kulturlandvogel im Neusiedlersee-Gebiet. *Vogelkundliche Nachrichten aus Ostösterreich* 4: 125–138.
- ELLENBERG, H. (1986) Warum gehen Neuntöter (*Lanius collurio*) in Mitteleuropa im Bestand zurück? Überlegungen zu den Auswirkungen von Pestiziden sowie zu den Landschaftsveränderungen im Winterquartier und im Brutgebiet. *Corax* 12: 34–46.
- FUISZ, T. I. (2002) A tövisszűrő gébics (*Lanius collurio*) fészkelőhely-választását, szaporodási sikerét és térfelhasználát befolyásoló tényezők. [Factors influencing the breeding site selection, breeding success and space use of Red-backed Shrikes (*Lanius collurio*)] In: MTA Emlékbeszédok, felolvasóülések illetve székfoglalók. [In press]
- HAAS, C. A. & OGAWA, I. (1995) Population trends of Bull-headed and Brown shrikes in Hokkaido, Japan. *Tech. Publ. West. Found. Vert. Zool.* 6: 72–75.
- HANDS, H. M., DROBNEY, R. D. & RYAN, M. R. (1989) *Status of the Loggerhead Shrike in the northcentral United States*. Unpubl. Rep. U.S. Fish Wildl. Serv., Missouri Coop. Fish Wildl. Res. Unit, Univ. Missouri, Columbia, Missouri.

- HARPER, A. M. & STORY, T. P. (1962). Reliability of trapping in determining the emergence and sex ratio of the sugar-beet root maggot *Tetanops myopaeformis* (Röder) (Diptera: Otitidae). *Can. Ent.* **94**: 268–71.
- HOLAN, V. (1993) Populační hustota a hnízdní bionomie t'uhky obecného (*Lanius collurio*) na Vsetínsku. *Sylvia* **29**: 3–11.
- HROMADA, M. & KRISTIN, A. (1996) Changes in the food of the Great Grey Shrike (*Lanius excubitor*) during the year. *Biologia Bratislava* **3**: 227–233.
- JACOBS, J. (1974) Quantitative measurement of food selection. *Oecologia* **14**: 413–417.
- JAKOBER, H. & STAUBER, W. (1987) Habitatsansprüche des Neuntötters (*Lanius collurio*) und massnahmen für seinem schutz. *Beih. Veröff. Natursch. Landschaft. Bad.-Württ.* **48**: 25–53.
- LEFRANC, N. (1979) Contribution à l'écologie de la Pie-grièche ecorcheur (*Lanius collurio* L.) dans les Vosges moyennes. *Oiseau* **1**: 245–298.
- LEFRANC, N. (1993) *Les Pies-grièches d'Europe, d'Afrique du nord et du moyen-orient*. Delachaux et Niestle, Lausanne. 240 pp.
- MALCHEVSKIY, A. S. & PUKINSKIY, Y. B. (1983) *Birds of Leningrad region and adjacent territories*. Leningrad Univ. Press, Leningrad.
- MARECHAL, P. (1993) Over externe factoren die de habitatkwaliteit van de Grauwe Klauwier *Lanius collurio* beïnvloeden. *Vogeljaar* **41**: 34–48.
- MILLS, G. S. (1979) *Foraging patterns of kestrels and shrikes and their relation to an optimal foraging model*. Ph.D. diss., Univ. Arizona, Tucson.
- MOSKÁT, C., FUJIMAKI, Y., YAMAGISHI, S. (2000) Perch site preference of the Bull-headed Shrike (*Lanius bucephalus*) during the breeding season in Japan. *Ring* **22**(1): 51–57.
- OLSSON, V. (1995) The effects of habitat changes on the distribution and population trends of the Great Grey and Red-backed Shrikes in Sweden. *Tech. Publ. West. Found. Vert. Zool.* **6**: 108–111.
- PANOW, E. N. (1996) *Die Würger der Paläarktis*. 2nd ed. Magdeburg.
- PEAKALL, D. B. (1962) The past and present status of the Red-backed Shrike in Great Britain. *Bird Study* **9**: 198–216.
- PEAKALL, D. B. (1995) The decline and fall of the Red-backed Shrike in Britain. *Tech. Publ. West. Found. Vert. Zool.* **6**: 112–116.
- PETERJOHN, B. G. & SAUER, J. R. (1995) Population trends of the Loggerhead Shrike from the North American breeding bird survey. *Tech. Publ. West. Found. Vert. Zool.* **6**: 117–121.
- PIELOU, E. C. (1975) *Ecological diversity*. Wiley, New York, 159 pp.
- PYKE, G. H., PULLIAM, H. R. & CHARNOV, E. L. (1977) Optimal foraging: a selective review of theory and tests. *Q. Rev. Biol.* **4**: 137–154.
- SCHÖNN, M. (1995) Habitat structure, habitat changes, and causes of decline in the Great Grey Shrike (*Lanius excubitor*) in southwestern Germany. *Proc. West. Found. Vertebr. Zool.*, **142–149**.
- SCHOENER, T. W. (1971) Theory of feeding strategies. *Annu. Rev. Ecol. Syst.*, pp. 369–404.
- SOUTHWOOD, T. R. E. (1966) *Ecological methods*. Chapman and Hall, London New York.
- STEPHENS, D. W. & KREBS, J. R. (1986) *Foraging theory*. Princeton Univ. Press, Princeton, New Jersey.
- TÓTHMÉRÉSZ, B. (1993) NuCoSa 1.0: Number cruncher for community studies and other ecological applications. *Abstracta Botanica* **17**: 283–287.
- TÓTHMÉRÉSZ, B. (1995) Comparison of different methods for diversity ordering. *J. Vegetation Science* **6**: 283–290.
- TÓTHMÉRÉSZ, B. (1996) *NuCoSa: programcsomag botanikai, zoológiai és ökológiai vizsgálatokhoz* (Nucosa: software package for botanical, zoological and ecological investigations.) Scientia Kiadó, Budapest, 84 pp.
- TÓTHMÉRÉSZ, B. (1997) *Diverzitási rendezések*. (Diversity ordering.) Scientia Kiadó, Budapest, 98 pp.

- TUCKER, G. M., HEATH, M. F., TOMIALOJC, L. & GRIMMETT, R. F. A. (1994) *Birds in Europe: their conservation status*. Birdlife Conserv. Series 3. Birdlife Int., Cambridge.
- TYRJANOWSKI, P., HRMADA, M. & ANTCZAK, M. (1999) Breeding habitat selection in the Great Grey Shrike *Lanius excubitor* – the importance of meadows and spring crops. *Acta. Orn.* **34**: 59–63.
- WAGNER, T. (1994) Brutzeitliches Beutespektrum des Raubwürgers *Lanius excubitor* auf Kahlschlag- und Windwurfllache im südwestfälischen Bergland. *Vogelwelt* **115**: 179–184.
- WEGGLER, M. (1991) *Brutvogel im Kanton Zürich*. Züricher Vogelschutz, Zürich.
- WHITEHEAD, S. C. & WRIGHT, J. (1994) Habitat use by Starlings *Sturnus vulgaris* flocks: A new method of assessing individual foraging performance. *J. Ornithol.* **135**: 183.
- YOSEF, R. (1994) Evaluation of the global decline in the True Shrikes (Family Laniidae). *Auk* 1994: 228–233.
- YOSEF, R. (1997) Two decades of studying bird migration at Eilat: a test case of conflicts and paradoxes. *Torgo* **28**: 109–117.
- YOSEF, R. & GRUBB, T. C. JR. (1993) Effect of vegetation height on hunting behavior and diet of Loggerhead Shrikes. *Condor* **95**: 127–131.
- YOSEF, R. & GRUBB, T. C. JR. (1994) Resource dependence and territory size in Loggerhead Shrikes (*Lanius ludovicianus*). *Auk* **111**: 465–469.
- YOSEF, R. & LOHRER, F. E. (1995) Shrikes (Laniidae) of the world: biology and conservation. *Proc. Western Found. Vertebrate Zool.* **6**: 1–343.
- YOSEF, R. & LOHRER, F. E. (1998) Shrikes (Laniidae) of the world: conservation implementation. *Int. Birding and Res. Center, Tech. Publ.* **7**: 1–119.
- YOSEF, R., CARREL, J. E. & EISNER, T. (1992) Contrasting reactions of Loggerhead Shrikes to two types of chemically defended insect prey. *J. Chemical Ecol.* **22**: 173–181.
- YOSEF, R., LAYNE, J. N. & LOHRER, F. E. (1993) Trends in numbers of Loggerhead Shrikes on roadside censuses in peninsular Florida, 1974–1992. *Fl. Sci.* **8**: 92–97.
- YOSEF, R. & WHITMAN, W. (1992) Predator exaptations and defensive adaptations in evolutionary balance: no defence is perfect. *Evol. Ecol.* : 527–536.
- ZAR, J. H. (1996) *Biostatistical analysis*. Prentice-Hall International, Inc. 662 pp.

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