

Supplementary information

Daniel A. F. Bloche*, Kasper Thorup, Kent Olsen, Per Ekberg, Peter Ellegaard Larsen, Knud-Erik Strange & Anders P. Tøttrup 2023: Breeding biology of Red-backed Shrikes (*Lanius collurio*): distribution, performance and post-fledging survival in Denmark. — *Ornis Fennica* 100: 00–00.

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Table S1. Classes in Corine Land Cover data of the year 2012 (CLC 2012) grouped into three main habitat types and their area in hectare (ha).

habitat type	area in ha	CLC classes
agricultural habitat	3283083.9	“agriculture and natural vegetation”, “arable land”, “complex cultivation pattern”, “pastures”, “fruit trees”
Forest	473370.7	”forests”, ”woodland-shrub”
semi-natural open habitat	229066.5	“beach and dunes”, “moors and heathlands”, “natural grasslands”, “wetlands”
synanthropic habitat	336689.1	”artificial surfaces”

Table S2. Number of points from breeding pairs of the Third Danish Breeding Atlas Survey for the years 2014 to 2017 (AtlasIII, n = 1534 pairs, Vikstrøm & Moshøj, 2020) and random points (n = 1534 per simulation) lying in different habitat types of the Corine Land Cover data of the year 2012 (table A2, CLC 2012). Chi-square test to calculate expected values and p-value with significance values (0 ‘****’ 0.001 ‘***’ 0.01 ‘**’ 0.05 ‘.’ 0.1 ‘ ’).

habitat type	number of AtlasIII breeding points	mean number of random points (SE)	p-value
agricultural habitat	678	1166.8 (0.5)	< 0.001 ***
forest	453	168.4 (0.3)	< 0.001 ***
semi-natural open habitat	224	80.6 (0.3)	< 0.001 ***
synanthropic habitat	179	118.2 (0.3)	0.002 **

Table S3. Poisson Generalized Linear Model for number of fledglings for DOFbasen data from the years 2000 to 2021 (n = 351 pairs, DOF, 2020), as well as project data from Mols Bjerger for the years 2010 to 2011 (n = 20 pairs), Rørvig for the years 2016 to 2021 (n = 55 pairs), Gribskov for the years 2006 to 2011 and 2018 to 2021 (n = 553 pairs), Melby Overdrev for the year 2021 (n = 4 pairs) and agricultural habitats in Northern Zealand for the year 2021 (n = 2 pairs). Model tested the factors: habitat type, year and both together. Anova test calculated degrees of freedom (df) and deviance for the values and residuals, as well as p-value with significance values (0 ‘****’ 0.001 ‘***’ 0.01 ‘**’ 0.05 ‘.’ 0.1 ‘ ’).

Factor	df	deviance	residual df	residual deviance	p-value
NULL			984	445.5	
habitat type	2	72.0	982	373.5	< 0.001 ***
year	21	49.3	961	325.1	< 0.001 ***
habitat type and year	39	41.2	922	282.2	0.373

Table S4. Poisson Generalized Linear Model for number of fledglings for DOFbasen data from the years 2000 to 2021 (n = 351 pairs, DOF 2020), as well as project data from Mols Bjerger for the years 2010 to 2011 (n = 20 pairs), Rørvig for the years 2016 to 2021 (n = 55 pairs), Gribskov for the years 2006 to 2011 and 2018 to 2021 (n = 553 pairs), Melby Overdrev for the year 2021 (n = 4 pairs) and agricultural habitats in Northern Zealand for the year 2021 (n = 2 pairs). Model tested the factors: habitat type and year, but Tukey-test only for factor habitat type. Tukey test calculated differences, lower and upper 95 % Confidence Interval (CI), as well as p-value with significance values (0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ').

factor: habitat type	difference	lower CI	upper CI	p-value
forest clearing – agricultural habitat	1.057	0.801	1.313	< 0.001 ***
semi-natural open habitat – agricultural habitat	-0.075	-0.214	0.364	0.813
semi-natural open habitat - forest clearing	-0.982	-1.165	-0.798	< 0.001 ***

Table S5. Poisson Generalized Linear Model for the number of fledglings for project data from Gribskov, Melby Overdrev and agricultural habitats in Northern Zealand for the year 2021 (n = 23 pairs). Model tested the factors: habitat type (Hbt), mean of calculated hatching date (Htc) and observations of potential avian nest predators (Eurasian Jay, Hooded Crow and Eurasian Sparrowhawk) per hour (Pph). Anova test calculated degrees of freedom (df) and deviance for the values and residuals, as well as p-value with significance values (0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ').

factor	df	deviance	residual df	residual deviance	p-value
NULL			22	8.2	
Hbt	2	0.4	20	7.8	0.827
Htc	12	3.1	8	4.8	0.995
Pph	8	4.8	0	0.0	0.784

Table S6. Poisson Generalized Linear Model for estimated hatching in day of the year of fledglings between forest clearings in Gribskov and open habitats (i.e. agricultural and semi-natural open habitats) for project data from Gribskov, Melby Overdrev and agricultural habitats in Northern Zealand for the year 2021 (n = 34 pairs). Model tested the factor: habitat type. Anova test calculated degrees of freedom (df) and deviance for the values and residuals, as well as p-value with significance values (0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ').

factor	df	deviance	residual df	residual deviance	p-value
NULL			22	6.2	
open habitat – forest clearing	1	0.76	21	5.5	0.385

Table S7. Poisson Generalized Linear Model for the number of fledglings for Denmark-wide data from DOFbasen for the years 2018 to 2021 (n = 48 pairs, DOF 2020), as well as project data from Rørvig for the years 2018 to 2021 (n = 47 pairs) and Gribskov for the years 2018 to 2021 (n = 247 pairs). Model tested the factor: area. Anova test calculated degrees of freedom (df) and deviance for the values and residuals, as well as p-value with significance values (0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ').

factor	df	deviance	residual df	residual deviance	p-value
NULL			341	154.9	
area	2	48.9	339	106.0	< 0.001 ***

Table S8. Poisson Generalized Linear Model for the number of fledglings for Denmark-wide data from DOFbasen for the years 2018 to 2021 (n = 48 pairs, DOF 2020), as well as project data from Rørvig for the years 2018 to 2021 (n = 47 pairs) and Gribskov for the years 2018 to 2021 (n = 247 pairs). Model tested the factor: area. Tukey test calculated differences, lower and upper 95 % Confidence Interval (CI), as well as p-value with significance values (0 ‘****’ 0.001 ‘***’ 0.01 ‘**’ 0.05 ‘.’ 0.1 ‘ ’).

factor: area	difference	lower CI	upper CI	p-value
Gribskov-DOFbasen Denmark	1.584	1.215	1.953	< 0.001 ***
Rørvig-DOFbasen Denmark	0.176	-0.304	0.656	0.665
Rørvig-Gribskov	-1.408	-1.781	-1.036	< 0.001 ***

Table S9. “Young Survival for marked adults” Cormack-Jolly-Seber models for the apparent survival rate per age in days after hatching $\phi(\text{age})$ using either a constant detection probability $p(\cdot)$ or an age-dependent detection probability $p(\text{age})$. The Models use encounter histories for each pair with ringed young (n = 8 pairs with 34 young) and are ranked according to their AIC value.

Cormack-Jolly-Seber model for Young Survival	AIC	Delta AIC	AIC weight
{ $\phi(\text{age})$ $p(\cdot)$ }	237.6	0.0	0.71
{ $\phi(\text{age})$ $p(\text{age})$ }	239.4	1.8	0.29

Table S10: Poisson Generalized Linear Model activity score from flying and hunting behaviour for the ringed fledglings at the project sites Gribskov, Melby Overdrev and agricultural habitats in Northern Zealand for the year 2021 (n = 74 observation visits). Model tested the factors: age in days of fledglings, pair and both together. Anova test calculated degrees of freedom (df) and deviance for the values and residuals, as well as p-value with significance values (0 ‘****’ 0.001 ‘***’ 0.01 ‘**’ 0.05 ‘.’ 0.1 ‘ ’).

factor	df	deviance	residual df	residual deviance	p-value
NULL			73	100.8	
age in days	1	33.0	72	67.8	< 0.001 ***
pair	7	15.4	65	52.4	0.031 *
age in days and pair	7	6.8	58	45.6	0.445

Table S11 Frequency of observations of flying behaviour (no, < 2 m, 2-20 m or > 20 m) of fledglings in different age groups for project data from Gribskov, Melby Overdrev and agricultural habitats in Northern Zealand for the year 2021 (n = 74 observation visits). Chi-square test to calculate expected values and p-value for difference between the groups: p = 0,001 ** (significance values: 0 ‘****’ 0.001 ‘***’ 0.01 ‘**’ 0.05 ‘.’ 0.1 ‘ ’).

Flying	group A (15 to 30 days)	group B (31 to 47 days)	number expected in Chi-square test group A	number expected in Chi-square test group B
> 20 m	11	30	19.4	21.6
2-20 m	12	7	9.0	10.0
< 2 m	6	2	3.8	4.2
no flying	6	0	2.8	3.2

Table S12. Poisson Generalized Linear Model for the percentage of pairs observed with non-familiar mixed fledglings and the age in days after hatching of the fledglings at the project sites Gribskov, Melby Overdrev and agricultural habitats in Northern Zealand for the year 2021 (n = 74 observation visits). Model tested the factor: age in days. Anova test calculated degrees of freedom (df) and deviance for the values and residuals, as well as p-value with significance values (0 '*** 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ').

factor	df	deviance	residual df	residual deviance	p-value
NULL			28	1431.5	
age in days	28	1431.5	0	0.0	< 0.001 ***

Table S13. Comparison of results for the mean productivity of successful pairs (F/sBP) from this study, Denmark-wide breeding bird observations from DOFbasen (n = 351 pairs, DOF 2020), Rørvig (n = 55 pairs), Mols Bjerger (n = 20 pairs), Gribskov, (n = 553 pairs), with other studies of stable local breeding populations.

Country	area	period	F/sBP	authors
Denmark	Denmark-wide	2000-2021	2.3	this study (DOFbasen)
Denmark	Rørvig	2016-2021	2.3	this study
Denmark	Mols Bjerger	2010-2011	3.7	this study
Denmark	Gribskov	2006-2011 & 2018-2021	3.6	this study
Denmark	Hulsig Hede	2003-2007	3.6	Jørgensen et al. (2013)
Netherlands	Bargerveen	2001-2009	4.0	Hemerik et al. (2015)
Poland	Leszno	1971-1979	4.2	Kuźniak (1991)
Sweden	Gryt	1956-1994	4.3	Olsson (1995)
Hungary	Aggletek National Park	1991-1996	4.3	Horvath et al. (2000)
Germany	Göppingen	1969-1985	4.4	Jakober & Stauber (1987)

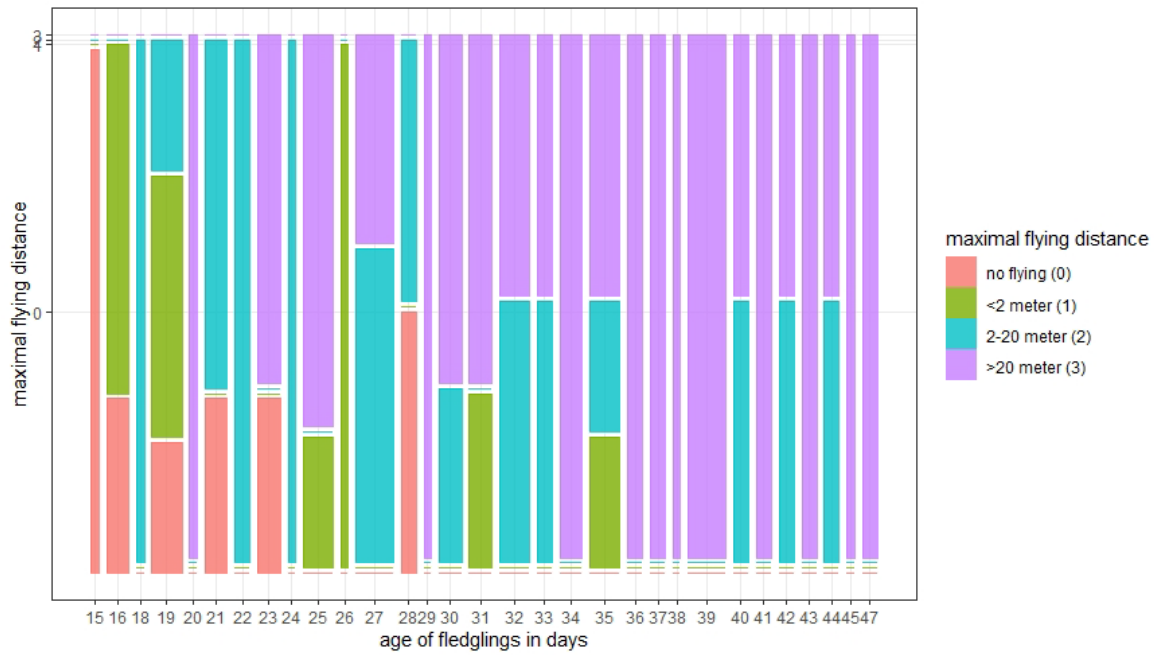


Fig. S1. Proportion of frequencies from observation of maximal flying distance of fledglings [no flying (0), < 2 m (1), 2-20 m (2) or > 20 m (3)] for project data from Gribskov, Rørvig and agricultural habitats in Northern Zealand for the year 2021 (n = 74 observation visits). The size of the bars indicates the differences in sample size between days.

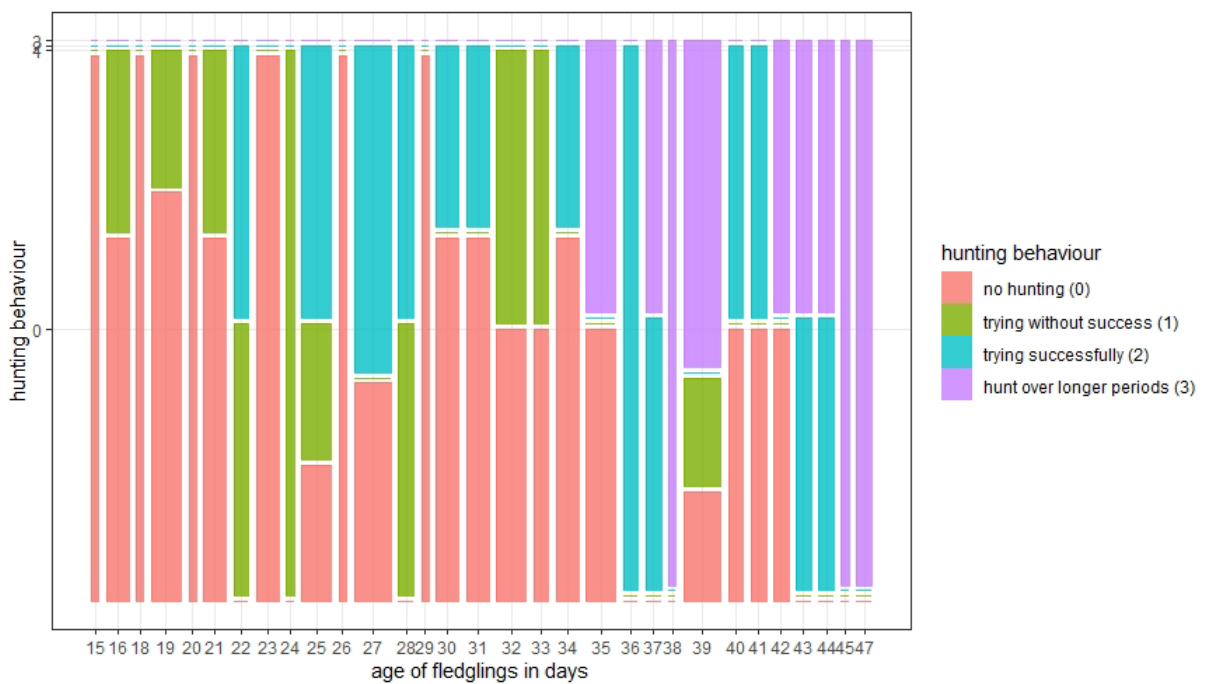


Fig. S2. Proportion of frequencies from observation of maximal flying distance of fledglings [no hunting (0), trying without success (1), trying successfully (2) or hunt over longer periods (3)] for project data from Gribskov, Rørvig and agricultural habitats in Northern Zealand for the year 2021 (n = 74 observation visits). The size of the bars indicates the differences in sample size between days.