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SHORT NOTE
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Southern grey shrike as a predator of reptiles on the island of Gran Canaria and a comparison between island and mainland predation rates

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INTRODUCTION

Reptiles may be present at relatively high population densities on arid islands, which despite low primary productivity, have the advantage of relatively stable temperatures and high ambient humidity due to their proximity to the sea (Novosolov et al., 2016; Santini et al., 2018); in these situations birds are probably the most important predators of reptiles (Greene, 1988). To compare arid islands with mainland areas in the extent to which they contribute reptiles as prey species for birds, it is necessary to investigate the diet of bird species that breed in both habitats. One such species is the southern grey shrike (*Lanius meridionalis*) that can be found on the island of Gran Canaria and elsewhere in south-west Europe and discontinuous areas of North Africa, the Middle East and the northern parts of the Indian subcontinent (Madroño et al., 2004).

The diet of the southern grey shrike has been studied by investigation of 1) faecal pellets (Soler et al., 1983), 2) the bodies of reptiles impaled on spiny substrates (Keynan & Yosef, 2010), and 3) prey delivered to the nest (Budden & Wright, 2000), reported as either the number of prey items and/or the percentage of biomass contributed by reptiles.

A subspecies of shrike, *L. m. koenigi,* is endemic to the Canary Islands and breeds on several islands to the centre and east of the archipelago (Tenerife, Gran Canaria, Fuerteventura, Lobos, Lanzarote, La Graciosa and Alegranza) (Martín & Lorenzo, 2001); this is the only bird species that impales reptiles in the Canary Islands. Many of the reptiles available as prey on the Canary Islands are both endemic and also restricted to only certain islands (Machado et al., 1985; Barbadillo et al., 1999). There have been no previous published studies on the diet of the southern grey shrike on Gran Canaria, where there are at least six reptile species – the lizards *Tarentola boettgeri*, *Chalcides sexlineatus* and *Gallotia stehlini* are native, *Gallotia atlantica* is considered to be introduced from nearby islands (Mateo et al., 2011; Mateo, 2015), and the gecko *Hemidactylus turcicus* and the snake *Lampropeltis californiae* are both alien species (Mateo et al., 2011). The current study was undertaken in order to - 1) document the reptile species that are impaled on spiny shrubs or barbed wire by the southern grey shrike on the island of Gran Canaria, and 2) following a literature review, to compare the importance of reptiles as food for the southern grey shrike on islands and in mainland habitats.

MATERIALS & METHODS

Study area and field work

The study area is located in the municipality of Agüimes (Gran Canaria), with geographic limits at 27º 53' 28.00'' N // 15º 23' 40.00" W; 27º 52' 17.06'' N // 15º 23' 59.80" W, bordering the Special Conservation Zone (ZEC) ES7010052 "Punta de la Sal". It comprised two adjacent areas, one with natural spiny vegetation (15 hectares) and the other (0.084 hectares) without spiny vegetation but instead with an 87 m barbed wire fence providing artificial 'spines'. The area is an extremely arid coastal habitat containing halophytic plant species adapted to the lack of water and aeolian erosion. At least three shrub species (*Lycium intricatum*, *Convolvulus caput-medusae* and *Launaea arborescens*) provide spines on which shrikes could impale prey.

Observations in the field were made over 21 days, between November 2015 and December 2016, in four periods, covering all seasons (Table 1). During this time all the shrubs with potential as substrates for impalement and the barbed wire were visited and checked. The impaled prey could often be identified to species (which is not always possible for observations of pellets or prey delivered to the nest).

Inspections were made early in the morning and suitable shrubs and barbed wire were examined thoroughly. Exact geographic coordinates were taken for each impalement observation, as well as several photographs for subsequent identification of the species impaled. Impalements were left intact with a concealed white paper label attached to the branch next to each observation within each study period, to avoid subsequent duplications.

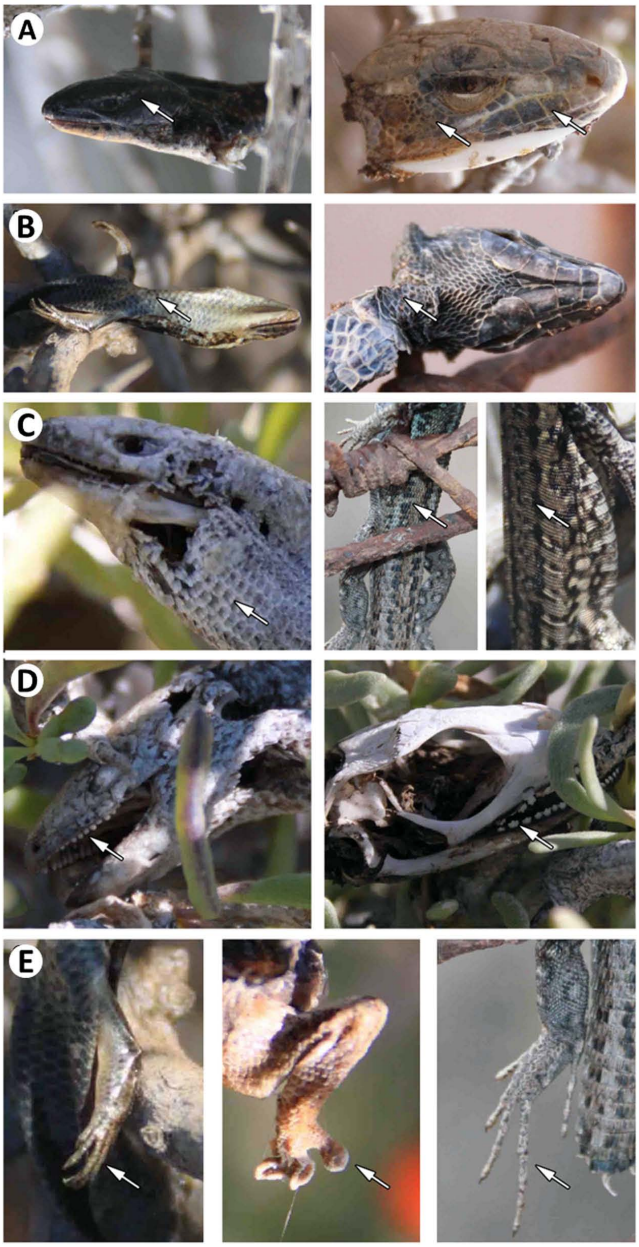

Figure 1. Criteria employed in reptile species identification- **A.** Scale shape along the head and number of labial scales (from left to right: Chalcides - regular scales; *G. stehlini* - irregular and five labial scales in front of subocular); **B.** Scale morphology (Chalcides - homogeneous; Gallotia - heterogeneous, smaller in the neck); **C.** Scale distribution (Chalcides - imbricate, they divide into three while they degrade, *G. atlantica* - low number of scale rows; *G. stehlini* - high number of rows); **D.** Dental cusps (Chalcides - one cusp; *G. stehlini* - three cusps); and **E.** Limb details (Chalcides - short; Tarentola - rounded; Gallotia - long).

For reptile species identification, we have followed Barbadillo et al. (1999) and special consideration was given to 1) the shape and scales of the skull, 2) the number of dental cusps, 3) the number and types of scales along the body, and 4) the shape and length of the limbs and fingers (Fig. 1).

Bibliographical review

During the first months of 2019, an exhaustive bibliographical search was made using search engines (Web of Knowledge and Google Scholar), with the following search terms: '*Lanius meridionalis*', '*Lanius excubitor*', 'bird predation on reptiles' and 'insular predation' (note that the southern grey shrike was formerly known as *Lanius excubitor*). The following information was extracted:

a) Country, province or island hosting the study

b) Form of sample (pellets, impaling or prey delivered to the nest)

c) Diet composition. Percentage of reptiles as a function of the total number of prey, and biomass percentage contributed by reptiles (when possible). Percentages were calculated as follows: when the study reported several species of reptiles separately, the percentages of each reptile species were added to calculate the percentage of reptiles as a whole over the total number of prey items consumed (with the biomass percentage calculated in the same way). When the diet was studied in different places within the same island or local administrative division, an average value was calculated. However, when the same study provided information on several different administrative divisions or islands, each area was treated separately. When monthly or seasonal data were provided, the annual average was calculated.

d) Predated species and families were recorded for each study. Prey items were considered as 'unidentified' when the family but not the species was mentioned. Some studies mentioned reptiles in the diet in a general way, although the species or family were not provided (e.g. Budden & Wright, 2000; Hódar, 2006; Lepley et al., 2004; Taibi et al., 2009). In all cases the percentages of prey or biomass were included when this information was available.

Statistical analyses

For the Gran Canaria data, a contingency table of counts of the total number of reptiles and other taxa (found impaled) on season were compared using a Fisher's Exact Test, considering only sampling periods 2, 3 and 4, in which the impalement period was known (period 1 observations included impalements that occurred at an unknown time before that period).

Four subsets of data were built following the literature review to compare 1) the percentages of reptiles as a proportion of the whole diet between the three forms of sample - impalement, pellet or nest delivery (n = 16); 2) basis of analysis - prey number or biomass percentage on pellets (n = 17); 3) pellets examined on mainland or island study areas compared by prey number (n = 11); 4) and the same as 3) but compared by prey biomass (n = 6).

The medians of groups of data were compared using the non-parametric Kruskal-Wallis test, Dunn's post-hoc test was used subsequently to make comparisons when there was more than two groups. The analyses were carried out in R, version 3.5.2. (R Core Team, 2018).

RESULTS

Impalement of reptiles by southern grey shrike on Gran Canaria

Reptiles were found both on shrubs (mainly *Lycium intricatum* but also *Plocoma pendulata* and *Juniperus turbinata*) and on the barbed wire. There was a total of 64 impalements (Table

1) that included three native reptile species (*T. boettgeri*, *C. sexlineatus* and *G. stehlini*), one introduced species *G. atlantica* and six degraded specimens that were identified as just *Gallotia* sp. Other taxa were also impaled, a single mouse (*Mus musculus*) and six insects (*Orthoptera* and *Coleoptera*). The impalements were recorded in four sampling periods (Table 1) and an analysis across these periods suggests that the counts of all impaled reptile prey and other taxa were not contingent on season (Fisher's Exact Test for Count Data, $p = 0.4$).

Table 1. Numbers of impaled reptile species and other taxa at various intervals from November 2015 to December 2016 on the island of Gran Canaria

Prey	Nov-Feb 2015-2016	Mar-Apr 2016	July-Sept 2016	Dec 2016	Total	% of all prey
Tarentola boettgeri	0	1	0	3	**4**	6.25
Chalcides sexlineatus	19	2	2	3	**26**	40.63
Gallotia stehlini	6	4	1	0	**11**	17.19
Gallotia atlantica	3	7	0	0	**10**	15.63
Gallotia sp.	3	1	0	2	**6**	9.38
Mus musculus	0	0	1	0	**1**	1.56
Insecta	2	2	1	1	**6**	9.38
Total reptiles	31	15	3	8	**57**	89.06
Total other taxa	2	2	2	1	**7**	10.94
Total of all prey	**33**	**17**	**5**	**9**	**64**	100

Bibliographical review

A total of 21 studies (22 with our study) provided information on reptiles predated by southern grey shrike, on five islands and eight mainland sites. Of these studies, eight present only an indication of the predated reptile species, the others list both the reptile species and give estimates of reptiles as a proportion of the total number of prey or as percentage of prey biomass. The full results including all 22 studies can be seen in Supplementary Materials (Table S1) while those with more detailed prey data are shown in Table 2.

Regarding the percentage of prey attributable to reptiles, observations of impalements revealed a considerably greater proportion of reptile prey than by observation of pellets or deliveries to nests (Fig. 2). However, statistically significant differences were only found between impalements and pellets (Dunn's post-hoc test: $p < 0.05$).

The biomass percentage of reptiles was obtained only in the studies on pellets, and this was greater than the percentage of reptiles as prey due to the large size of reptiles compared to other prey taxa such as insects (Kruskal-Wallis, $\chi 2 = 5.82$, $p < 0.05$, $df = 1$) (Fig. 2).

The biomass of reptile prey in pellets was greater from islands than mainland habitats (Kruskal-Wallis, $\chi^2 = 3.86$, $p < 0.05$, $df = 1$) (Fig. 2).

Table 2. Data from a bibliographical review and the current study on the reptile prey (all lizards) of the southern grey shrike from mainland or island habitats, showing the form in which the prey was sampled (impalements, pellets or nest deliveries), percentage of reptiles as a function of the total number of prey (% P) and/or percentage of biomass contributed by reptiles (% B)

Form of sample	Location	% P	% B	Phyllodactylidae	Scincidae	Lacertidae	Reference
Observations from mainland habitats							
Pellets	Granada, Spain	0.52					Soler el al., 1983
	León, Spain	2.29					Hernández et al., 1993
	France		1.43				Lepley et al., 2004
	Granada, Spain	10.15	27.31				Hodar, 2006
	Algeria	0.76					Taibi et al., 2009
	Algeria	5.46	45.73		*Chalcides ocellatus*	Unidentified	Taibi et al., 2018
Impalements	Badajoz, Spain	44				*Psammodromus hispanicus* *Lacerta lepida*	Hernández & Salgado, 1993
	León, Spain	16.8					Hernández, 1995
Nest	Israel	7.8					Budden & Wright, 2000
	Granada, Spain	1.18				Unidentified	Moreno-Rueda et al., 2016
Observations from island habitats							
Pellets	Fuerteventura, Spain	4.6		*Tarentola angustimentalis*		*Gallotia atlantica*	Grimm, 2005
	Lanzarote, Spain	10.8				*Gallotia atlantica*	Grimm, 2005
	Tenerife, Spain	3.8				*Gallotia galloti*	Grimm, 2005
	Tenerife, Spain	3.27	65.85	*Tarentola delalandii*		*Gallotia galloti*	Padilla et al., 2005
	Lanzarote, Spain	17.0	68.75			*Gallotia atlantica*	Padilla et al., 2009
	Tenerife, Spain	6.74	72.91			*Gallotia galloti*	Padilla et al., 2009
Impalements	Gran Canaria, Spain	89.06		*Tarentola boettgeri*	*Chalcides sexlineatus*	*Gallotia atlantica* *Gallotia stehlini*	This study

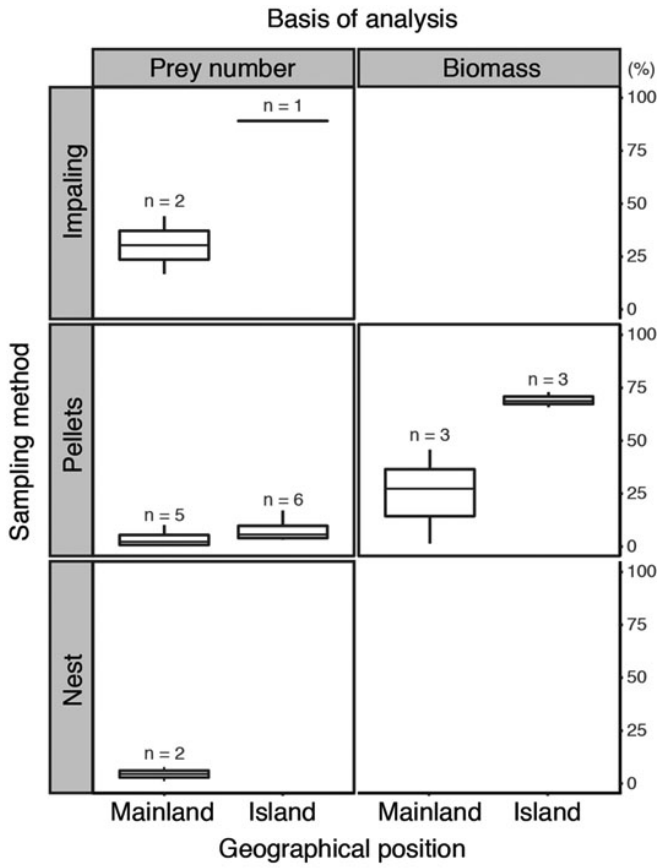

Figure 2. Box and whisker plot of data from the current study and literature (Table 2) for the percentage of reptiles prey items or of percentage reptile biomass in the diet of the southern grey shrike, sorted by study area (mainland and island) and form of sample (impalements, pellets or nest deliveries)

DISCUSSION

How sample form affects the study of diet

The form in which the sample was taken in each study had an important influence on the results. Observations of impaled prey provided higher percentages of reptiles than the other two techniques (i.e. pellets or prey delivered to the nest by the parents). This may be a result of southern grey shrikes mostly impaling only larger prey, small prey perhaps being consumed directly. Three of the seven impalement studies reviewed provided the percentages of reptiles with respect to the total number of prey consumed; in all these, percentages were quite high: 44 % (Hernández & Salgado, 1993); 16.8 % (Hernández, 1995), and 89.06 % (this study).

Reptiles in the diet of the southern grey shrike on the island of Gran Canaria

The diet of the southern grey shrike has previously been studied in the Iberian Peninsula, France, Israel, Yemen and Algeria as well as on other islands of the Canary archipelago (Table 2, Table S1). Despite the limitation of existing studies and considering that small sample sizes in statistical analyses mean that it was difficult to detect any differences, results presented here suggest that regardless of the form of sample and analysis type, reptiles are more common prey on islands than in mainland areas (Fig. 2).

This study presents the first information on the diet of the southern grey shrike in Gran Canaria. This bird species preys on the three native species (*T. boettgeri*, *C. sexlineatus* and *G. stehlini*), and the introduced species *Gallotia atlantica* (Mateo et al., 2011; Mateo, 2015). It can be suggested that the southern grey shrike does not show a clear food preference for a particular species or group, and that its diet is probably more conditioned by prey availability.

Opportunistic character of the southern grey shrike

The southern grey shrike feeds on the potential reptile families present at each site, as has been confirmed both in the island of Gran Canaria (Table 1) and in the other places where its diet has been studied (Table 2, Table S1), confirming their relative importance in its diet.

On many islands, the southern grey shrike remains in the same areas throughout all seasons of the year, probably because of the stable island climate and food availability; on Gran Canaria reptiles are active throughout all the year (Padilla et al., 2007 & 2009). On the contrary, the mainland southern grey shrikes have to migrate during winter (Madroño et al., 2004).

Studies of pellets in mainland areas demonstrate that the diet of the southern grey shrike diet consists mainly on invertebrates (*Coleoptera*, *Orthoptera* and *Hymenoptera*) and that the consumption of reptiles is greater during the warmer months of the year when they are active (Soler et al., 1983 & Hodar, 2006). Nevertheless, according to Hernández et al. (1993), for most of the year vertebrates make a greater calorific contribution than invertebrates to the diet of the southern grey shrike.

Statistical analysis of this study suggests a higher abundancy of reptiles in the diet of the southern grey shrike on islands than in mainland areas. Further studies should be made to confirm this pattern with special attention to making comparisons of the two habitats at the same time of year.

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