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The yellow-legged gull as a predator of lizards in Balearic Islands

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Abstract. Lizards and gulls cohabit in several Mediterranean islands. The yellow-legged gull, *Larus michahellis*, was found to prey several vertebrate species. However, precise information about the interaction between gulls and other vertebrates, particularly with lizards is still scarce. The Balearic lizard, *Podarcis lilfordi*, shares several coastal islets with the yellow-legged gull. Using two different sources of information, we studied the interaction of both species in Colom Island (Menorca, Balearic Islands, Spain). We studied the diet of the yellow-legged gull and learnt that the Balearic lizard is not a common prey of the yellow-legged gull. On the other hand, we studied the potential predation pressure of gulls on lizards, using plasticine models of lizards. We did two different experiments from which we can conclude that yellow-legged gulls rarely attack lizards and, consequently, cannot be considered a major threat for this endemic lizard species, at least in the population under study. Finally, we obtained evidence that plasticine models can only be employed with caution to assess predation pressure of opportunistic scavengers, much as gulls are. The majority of marks on models were not the consequence of true attacks by gulls, but the result of ground exploratory behaviour of gulls in search of any edible matter. Therefore, contrary to popular belief, in the case of the yellow-legged gull, the proportion of marked models would be an indication of ground-based wandering activity, rather than a result of its predation pressure on lizards.

Keywords: islands, Lacertidae, *Larus michahellis*, *Podarcis lilfordi*, predation pressure, prey models.

Introduction

One of the most common methods to study the potential influence of avian predators on terrestrial prey is the use of replicas of prey made in a soft material that allow to detect the attack from different predatory species (see, for example, Brodie, 1993; Brodie and Janzen, 1995; Shepard, 2007). The method was used to study the predation pressure on some lacertid lizards as *Podarcis atrata* from Columbretes Islands (Spain) by Castilla and Bauwens (1996) and Castilla and Labra (1998), *P. muralis* (Diego-Rasilla, 2003) from areas of the Iberian Peninsula and to estimate the predation pressure from kestrels on lizards from the genus *Gallotia* on Canary Islands (Cejudo et al., 1999).

In several Mediterranean islands and islets, lizards coexist with sea birds. In Balearic Islands, gulls are potential predators of lizards, particularly the widespread yellow-legged gull, *Larus michahellis*, but also the Audouin's gull, *Ichthyaetus audouinii*. According to certain studies, the yellow-legged gull can be a serious threat for other vertebrates. For example, gulls can displace other bird species from breeding areas as was shown in the case of the slender-billed gull, *L. genei* or the Audouin's gull, *I. audouinii* (Paterson, 1997). Some authors even detected negative effects on soil and vegetation of breeding areas (Bermejo and Mouriño, 2003) or they stressed the role of gulls as pathogen vectors (Bosch and Muniesa, 1996). However, at Medas Islands (NE Spain), no harmful effects were detected in breeding colonies of herons (Bosch et al., 1994). In fact, today there is increasing evidence that yellow-legged gulls have lower negative effects than previously thought. Oro et al. (2005) showed that the predatory behaviour of gulls on breeding colonies of storm petrels, *Hydrobates pelagicus*, is not widespread amongst gulls, but only characteristic of a few individual specialists. Prunier (2003) at Dragonera Island (Balearic Islands, Spain) and Martínez-Abraín et al. (2003) in Delta del Ebro, Chafarinas Islands and Columbretes Islands (Spain), were unable to detect any negative effect of the yellow-legged gull on Audouin's gulls. Furness and Monaghan

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(1987) found similar results for other sea bird species (see a review in Oro and Martínez-Abraín, 2007).

It is due to these conflicting results that this work analyses the potential role of the yellow-legged gull as a predator of the Balearic lizard, *P. lilfordi*, in a coastal islet of Menorca Island where both, lizards and gulls, are extremely abundant. At the same time, we evaluate the usefulness of plasticine models to assess the predation pressure of generalized predators as gulls on lizard populations.

Material and methods

Study area and species under study

Colom, with a surface of 59 hectares, is the largest coastal islet of Menorca (Balearic Islands, Spain, fig. 1). At least from the fifth century, Colom was occupied by humans (Fernández, Juaneda and Mayol, 1999). Today, it is uninhabited and within the Natural Park of s'Albufera des Grau. Colom is located in the geologically oldest area of Menorca, with a dominance of Palaeozoic rocks, mainly from the Carboniferous period (Fernández, Juaneda and Mayol, 1999). The climate is Mediterranean, with an annual average temperature of 17°C and an average rainfall of 500 to 600 mm. The vegetation is formed by more than 220 vascular plants, with around 10% of endemic species and, even if the islet was occupied during a long period, introduced plants are scarce (Fraga et al., 2003). Colom is characterized by a higher diversity of potential predators or competitors on lizards than other coastal islets of Menorca. Ladder snakes, *Rhinechis scalaris* (Esteban et al., 1994), ship rats, *Rattus rattus*, kestrels, *Falco tinnunculus* and a large breeding colony of the yellow-legged gull are ever-present (Fernández, Juaneda and Mayol, 1999 and pers. obs.). Our study was conducted in five different areas of the islet: The North area, the Threshing floor area, the East area, the Southeast area and the South area (fig. 1).

The Balearic lizard, *Podarcis lilfordi* (Günther, 1874), is a medium-sized lacertid lizard endemic of the Balearic Islands. Its presence today is limited to coastal islets of Mallorca, Menorca and the Cabrera archipelago. Lizards were extinct on the main islands of Mallorca and Menorca around Roman times (Bailón, 2004). There are several hypotheses trying to explain this Holocenic extinction. Some of the most convincing ones point at introduced predators, especially small carnivorous mammals (Eisentraut, 1949; Mertens, 1957; Salvador, 1993; Pérez-Mellado et al., 1997).

Field methods and data analysis

We studied the diet of the yellow-legged gull with the analysis of 515 pellets obtained in Colom during March and April 2005. Remains were identified to the highest possible level. In the case of arthropods, the identification was generally done to order level. For vertebrates, we tried to identify prey to the species level. We did not differentiate between carcasses and living individuals for animal prey.

In order to test the methods traditionally employed to estimate the predation pressure of gulls on lizards, we did a series of experiments using plasticine models. Due to the large

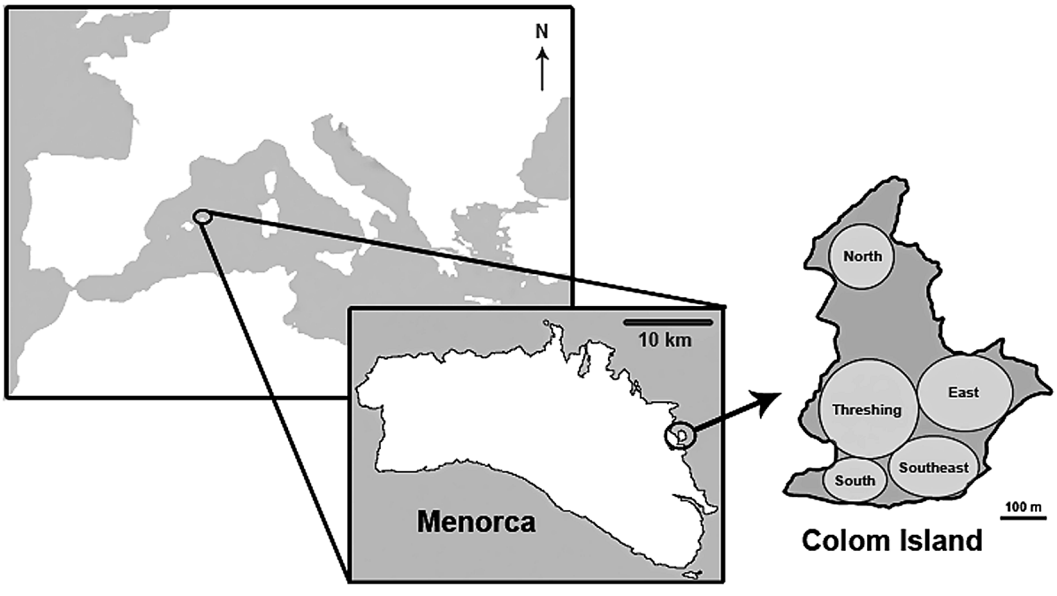

Figure 1. The study area. Situation of Menorca in Balearic Islands and Colom Island. To the right, the five areas of Colom Island where the study was done (see more details in the text).

number of replicas of plasticine models that can be used, these are considered an effective method to estimate attack rates by predators on reptiles (see, for example, Castilla et al., 1999 and Vervust, Grbac and Van Damme, 2007). According to previous studies, predatory species, as avian raptors or mammals, can be distinguished from bites, beak and claw marks left on clay models surface (Castilla et al., 1999; Vervust, Grbac and Van Damme, 2007). We manufactured two different models. Firstly, very realistic lizard models were made with plasticine using a plaster cast moulded from a preserved specimen of an adult male of the Balearic lizard (65 mm of SVL from the Herpetological collection of Animal Biology Department, University of Salamanca). These models were made with brown-olive green plasticine, an average colour that covers the wide range of different back colours of lizard population inhabiting Colom Island (Pérez-Mellado and Salvador, 1988; Pérez-Mellado, 2006). A secondly further series of plasticine models of the same colour was made as geometric squared sticks of $65 \times 15 \times 15$ mm. Hence, one of the series of plasticine models were realistic lizard replicas and the other one consisted of fully geometric structures.

A first experiment with two replications was done two times in March and two times in April 2005, on each area of the island, except in the Southern area, where we did the experiment only two times in March and one time in April. For each experiment, we placed 100 realistic models within 5 m of each other. They were scattered over open ground areas and fully visible for avian predators. On each area of the island, models were placed during the whole period of lizard activity, defined by the time with direct solar incidence. By placing models only during the period of lizard activity during the day, we avoided the recording of models bitten by rodents at night. Before sunset, models were collected, recording those with any sign of damage or mark. In all cases, we tried to distinguish beak or claws marks from birds, when they were present or any other damage in the models. In addition, we noted the substrate type (rock, stony ground, rock fence, grass or sand) where the model was placed, its height above the ground, and the distance to closest shrub.

The second experiment was performed using 40 plasticine models, 20 realistic replicas and 20 geometric sticks (see above), alternatively placed within 2 m of each other. Models were situated in an open area and a hide of 2 m^3 was placed 10 m apart to make direct observations. Two observers recorded the behaviour of gulls. That is, they recorded the arrival, landing or walking of each individual gull and its behaviour, categorized as: standing up, walking, exploring ground objects and interacting with other gulls. The observers recorded the behaviour of gulls towards the models, that is, if they picked the models and the cases in which they crashed the models walking over them. Observations were performed during two hours in the morning and two hours in the afternoon, within the period of maximal lizard activity. The experiment was replicated four times in four areas of the island: East, North, South and Threshing floor area, excluding the Southeast area, where we observed significantly lower results with the first experiment (see Results).

All statistical analyses were done with JMP™ (ver. 5.0.1.2) and Statistica™ (ver. 6.0) packages. Data were analyzed with parametric tests. When they did not meet statistical requirements, data were analyzed with non-parametric equivalents (Zar, 1999). We employed the logistic regression to test the effect of different factors on the attack of plasticine models in the first experiment with 100 replicas. The factors taken into account were: the type of substrate where the model was located, the distance of the model to the closest shrub and the height above the ground of the model (see above). For each analysis, we calculated the likelihood ratio χ^2 (Sokal and Rohlf, 1995), testing the null hypothesis of the absence of effect of predictive variables on dependent variable Y (Quinn and Keough, 2002). In all cases we employed $\alpha = 0.05$.

Results

The diet of the yellow-legged gull in Colom

From pellet analysis, we obtained 626 different prey items (table 1) and 1369 inorganic remains, including different kinds of paper, plastic pieces and even a whole plastic razor! The diet of the yellow-legged gulls of Colom is varied with the inclusion of all small mammals recorded in the islet. Some of these mammals could also be captured in Menorca Island, as the brown rat, *Rattus norvegicus*, absent from Colom. Also several fruit remains and olives were obtained in Menorca. We also recorded the presence of several bone remains from fish to shells from different mollusc species. Amongst reptiles, only two Moorish geckos, *Tarentola mauritanica*, were recorded.

Experiment with lizard models

In the first experiment with realistic models, we did not find significant differences between the two replications in any of the tested areas of the island (chi-square tests, $P > 0.05$ in all cases). Thus, both replications were pooled in further analyses. Regarding the percentage of attacked models in each area, our results show that a significantly higher rate of attacks was recorded in the Northern ($P < 0.001$ in the comparisons with the rest of the areas) and Eastern areas ($P < 0.01$ in the comparisons with the rest of the areas). In logistic regressions, we found that

Table 1. The diet of the yellow-legged gull, *Larus michahellis*, in Colom Island. For each identified prey type, we give N: the number of individual prey recorded, %N: the percentage of each prey type and %P: percentage of pellets where a prey type was present.

Prey type	N	%N	%P
Mammals			
Mus spretus	1	0.16	0.19
Rattus rattus	5	0.79	0.97
Rattus norvegicus	2	0.32	0.38
Rattus sp.	4	0.64	0.77
Oryctolagus cuniculus	4	0.64	0.77
Unidentified mammals	35	4.95	6.02
Total mammals	**47**	**7.51**	**9.13**
Total birds	**92**	**14.69**	**17.47**
Tarentola mauritanica	2	0.32	0.38
Total reptiles	**2**	**0.32**	**0.38**
Egg remains	26	4.15	5.05
Fishes	**84**	**13.42**	**16.31**
Invertebrates			
Mytilus spp.	21	3.35	4.07
Gastropoda	15	2.40	2.91
Unidentified mollusks	84	13.42	16.31
Diplopoda	1	0.16	0.19
Isoptera	1	0.16	0.19
Coleoptera	69	11.02	10.87
Crustacea	6	0.96	1.16
Total invertebrates	**197**	**31.47**	**35.73**
Plants			
Olea sp.	32	5.11	4.66
Helianthus sp.	53	8.46	3.11
Juglans sp.	6	0.96	1.16
Cucumis sp.	7	1.12	0.58
Citrillus sp.	9	1.44	0.39
Pistacia sp.	2	0.32	0.19
Pinus spp.	2	0.32	0.39
Vitis sp.	1	0.16	0.19
Unidentified seeds	62	9.90	6.40
Total plants	**174**	**27.80**	**17.09**
TOTAL	**626**		

there is a positive relationship between the distance of the closest shrub and the probability of being attacked. In other words, the probability of attack increased with the distance to the closest refuge ($\chi^2 = 52.61$, $P < 0.0001$). We did not find any relationship between attack probabilities and the remaining factors taken into account.

Observations of gulls

In several cases, while hiding, we observed that walking gulls detected a model of any of both designs without any apparent interest, even stepping on it. In other cases, gulls picked models as many other objects including plastic pieces, papers, small rocks or bottle caps. We only recorded a case in which a gull attacked a model from the air, capturing it and immediately discarding it.

For each of the four areas, we pooled the number of picked and crashed models to compare larger sample sizes within each replication. Even then, we only have frequencies above 5 in the case of Threshing and Eastern areas (see online Supplementary table S1). In almost all replications, the number of picked models was slightly higher for realistic lizards, but in no case did we find significant differences in the proportion of both models (chi-square test, $P > 0.05$ in all trials). The overall analysis of the results from the four areas under study also showed no differences between both models ($\chi^2 = 3.07$, $P = 0.08$ for picked models, 21 geometric models versus 34 realistic models and $\chi^2 = 2.49$, $P = 0.12$ for crashed models, 23 geometric versus 35 realistic models) (see online Supplementary fig. S1).

Discussion

Even if with a few exceptions, the studies of Mediterranean sea birds considered the yellow-legged gull as an important threat, these citations are based on popular belief, rather than evidential proofs (Oro and Martínez-Abrían, 2007). It has been shown that gulls occasionally capture reptiles (Martín and López, 1990; Oro and Martínez-Abraín, 2007; Matias and Catry, 2010) as a part of a very diverse diet that includes organic matter from several origins (Cramp et al., 1983). In our case, we see that the diet of the yellow-legged gull nesting in Colom islet was based on marine organisms, such as fish and molluscs, with a complementary contribution of small mammals and birds. Reptiles are presenting only a very small proportion in their diet, since we recorded the presence of bone remains solely from two individu-

als of the Moorish gecko, *T. mauritanica*. Even though the Balearic lizards are much more common than Moorish geckos, on the Colom Island (Pérez-Mellado et al., 2003), no remains of them were found in our study.

We do not discard that gulls may sporadically predate on lizards because, for example, on Aire islet (Menorca, Balearic Islands), a juvenile of the Audouin's gull regurgitated three Balearic lizards, clearly fed by parents (Mayol, pers. comm. and Pérez-Mellado, 2006). In addition, the extensive studies of the diet of *I. audouinii* did not record consumption of lizards as a habit (Oro et al., 1996; Ruiz et al., 1996; Muntaner, 2003 and references therein).

Whilst studying lizard behaviour on Colom islet, we observed landed gulls slowly walking through areas amongst several basking lizards. In some cases they would attempt to capture them, but we did not witness any success in doing so. At least in our case, if geometric and realistic models showed a similar proportion of marks, it was not because gulls indiscriminately attacked both models, but because models were explored, picked or stepped as novelty objects by wandering gulls (see Supplementary figs S2 and S3). This was not as a part of a true predatory behaviour, as we observed in our experiments while hiding. Nevertheless, other authors were able to observe successful attacks in Columbretes Islands (Castilla and Bauwens, 1996; Castilla and Labra, 1998). Apparently, in the first paper two kinds of models were employed, a plasticine model and a chalk geometric model covered with latex and painted with some different colours (Castilla and Bauwens, 1996). Meanwhile, in the second paper results were presented only for plasticine realistic models (Castilla and Labra, 1998). Castilla and Bauwens (1996) justified the usefulness of geometric models in two previous papers from Smith (1973, 1976) in which prey were imitated with non-realistic models. However, it is highly doubtful that birds are able to identify as true prey those geometric models. Firstly, Smith (1973) used non-realistic models in a very particular context, to study the development of attack behaviour in young loggerhead shrikes, *Lanius ludovicianus*. In fact, Smith (1973) concluded that the response to still features added to models (i.e., eye spots or a differentiated head), could be due, partly or entirely, to curiosity. Secondly, Smith (1976) concluded that only movements of the geometric replicas attracted visual predators.

Hence, the problem is how to interpret the results when models are placed in the field and checked several hours later, without a direct observation of predator's behaviour. For example, Shepard (2007) made a study of predation on lizards in Brazilian "*Cerrado*". In most cases, his models had marks that could not be assigned to a specific predator (see online Supplementary fig. S4). Consequently, the majority of models were assigned to an unknown category, but even then, they were classified as truly attacked models (Shepard, 2007). Vervust, Grbac and Van Damme (2007) also interpreted all marked plasticine models as actual attacks by different avian predators, after a 48 to 52 hour exposure to potential predators.

However, our direct observations while we were hiding showed that models were picked or crushed by gulls much as many other random natural and artificial objects found during a general exploratory behaviour of wandering on the ground, while they were searching for any edible matter. In our opinion this behaviour cannot be considered as predatory attack on a free-living lizard. In Colom we never observed even an attempt of capture of an immobile (i.e., basking) lizard by a wandering gull. Almost any visible object is explored and/or picked by gulls. Several artificial objects are swallowed by gulls in that way, as the analysis of pellets showed. Hence, at least in the case of gulls, we suggest that reliable conclusions about predation pressure on lizards cannot be done by using this kind of protocol in which models are left for hours without direct observation by experimenters. We have shown that marks on the plasticine models are not a reliable estimation of the

true predatory attacks of gulls. In our case, the proportion of injured models was a reflection of the general terrestrial activity of gulls on a given area, and not only of their predation attacks.

Plasticine models should not be discarded as a tool to study predation pressure on natural populations. These models can be a very useful method when we take into account the particular foraging behaviour of involved predators. With sauriophagous avian predators, as kestrels or shrikes, whose marks can be unambiguously identified (Castilla et al., 1999; Diego-Rasilla, 2003; Husak et al., 2006), the use of models can be really useful. Probably, it is also the case of other successful studies where terrestrial prey are attacked by a variety of different predatory species (Brodie, 1993; Brodie and Janzen, 1995; Shepard, 2007). With omnivorous gulls, able to search or forage on the ground, true attacks on models are much more difficult to be established without a direct observation of their foraging behaviour. Beckers, Leenders and Strijbosch (1996) even pointed out that the use of models could be suitable in some studies but that we would need to take into account that models on plasticine, rubber or wood are substantially different than living prey and that these differences can be clearly perceived by visual predators. Thus, it would be necessary to test the behaviour of predators towards dummy models to ensure that such behaviour is similar to predatory attacks towards living prey (Beckers, Leenders and Strijbosch, 1996).

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