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EVIDENCE OF NICHE EXPANSION IN THE *MYOTIS PUNICUS* (*Mammalia Chiroptera*) OF THE MALTESE ISLANDS

SUMMARY

Habitat degradation and destruction due to post-war population expansion and the local extinction of *Rhinolophus ferrumequinum* have brought about changes in the ecosystem structure of the Maltese Islands. This might have had an effect on the local *Myotis punicus* population, the largest species currently inhabiting these islands. This study was carried out in an attempt to determine if due to the reduction in food resources and the absence of interspecific competition, *M. punicus* in Malta might exhibit niche expansion to reduce the intraspecific competition. This in turn would have an effect on the measurable phenotypic traits. Data for six morphometric variables was collected from *M. punicus* individuals captured from 11 different localities around the islands of Malta and Gozo. Forearm length, ear length and weight were compared with those of *M. punicus* from Sardinia, Corsica and Morocco.

RIASSUNTO

Evidenze dell'ampliamento della nicchia nel Myotis punicus *delle isole Maltesi*. Il degrado e la distruzione dell'habitat causati dall'espansione della popolazione umana post-bellica e l'estinzione locale del *Rhinolophus ferrumequinum* hanno causato dei cambiamenti nella struttura dell'ecosistema delle isole Maltesi. Questo potrebbe avere avuto un effetto sulla popolazione locale di *Myotis punicus*, la specie più grande attualmente abitante su queste isole. Questo studio è stato effettuato nel tentativo di stabilire se a causa della riduzione delle risorse alimentari e dell'assenza di competizione interspecifica, *M. punicus* a Malta può avere subito un'ampliamento della nicchia ecologica, per ridurre la competizione intraspecifica. Questo a sua volta avrebbe un effetto sulle caratteristiche fenotipiche misurabili. Sono stati raccolti dati di sei variabili morfometriche da individui di *M. punicus* catturati in 11 diverse località delle isole di Malta e Gozo. La lunghezza dell'avambraccio, la lunghezza dell'orecchio e il peso sono stati confrontati con quelli di *M. punicus* della Sardegna, della Corsica e del Marocco.

INTRODUCTION

Myotis punicus Felten 1977, commonly known as Felten's Myotis, Maghrebian Myotis or Maghrebian mouse-eared bat and locally known as 'Farfett il-Lejl Widnet il-Gurdien', is the only *Myotis* species inhabiting the Maltese Islands. It has been described as a genetically distinct species from *M. myotis* and *M. blythii* based on both morphometric (BENDA & HORÁČEK, 1995; ARLETTAZ *et al.*, 1997; EVIN *et al.*, 2008) and genetic data (CASTELLA *et al.*, 2000).

The distribution of *Myotis punicus* stretches over western North Africa, covering from Morocco, through Algeria and Tunisia, reaching Tripolitania in north-west Libya and northwards to the European islands of Malta and Gozo, Corsica and Sardinia (FELTEN *et al.*, 1977; ARLETTAZ *et al.*, 1997; BORG, 1998; CASTELLA *et al.*, 2000; MUCEDDA & NUVOLI, 2000; TOPÁL & RUEDI, 2001; BEUNEUX, 2004).

On the Maltese Islands the ever-increasing demand for land resulting in habitat degradation and destruction has lead to severe declines over the past 30 years in most bat populations including that of *M. punicus* and possibly the local extinction of *Rhinolophus ferrumequinum* (BARON, 2007). However, since *M. punicus* is an opportunistic gleaning bat, the question arises whether the extinction of *R. ferrumequinum* and the reduced food resources available as a result of habitat disturbance and heavier pesticide use to meet agricultural needs have had an effect on *M. punicus* and whether these pressures have lead to any observable phenotypic changes in the local population.

The expansion of the ancestral niche to new resource types or environments referred to as niche invasion (SCHLUTER, 2000) in general leads to character release (GRANT, 1972) i.e. an increase in phenotypic variance (Van VALEN, 1976; BOLNICK, 2001). Increased variance in behaviour, morphology and/or physiology can occur rapidly in situations where the environment has unoccupied resources (JOHNSON & GULLBERG, 1998; SCHLUTER, 2000).

The reduced interspecific competition allows competition within a species to create pressure towards rapid diversification by increasing the fitness of individuals using previously sub-optimal resources (ROUGHGARDEN, 1972; WILSON & TURELLI, 1986). In addition, optimal foraging theory predicts that in order to maximise the net energy intake per unit time, the breadth of a dietary niche tends to expand as resource availability decreases (MACARTHUR & Pianka, 1966). With the preferred prey species becoming scarce as a result of changes in agricultural practices and habitat loss, bats are expected to broaden their diet to include less preferred and/or novel prey species (ARLETTAZ, 1996; JOHNSTON & BROCK FENTON, 2001).

This study was carried out in an attempt to determine if the loss of *R. fer-*

rumequinum and the extensive disturbance due to post-war population expansion that have brought about changes in the insular ecosystem structure have also had an effect on the Maltese *M. punicus* population. The hypothesis is that with a reduction in resources and no interspecific competition, *M. punicus* in Malta might exhibit niche expansion to reduce the intraspecific feeding competition. This in turn would have an effect on the measurable phenotypic traits.

It is anticipated that knowing more about the ecological niche occupied by *M. punicus* in the local ecosystem would help in understanding its value and how to provide adequate protection when drawing up local plans for the conservation of this species.

Materials and methods

The data used were collected from individuals of *M. punicus* captured from 11 different localities around the islands of Malta and Gozo. Mist nets and hand nets were used depending on the site being sampled. When mist nets were used, these were set up at the openings of roosts or foraging sites 1 hour before sunset.

Any newly captured individuals were ringed (rings used bear the indication of the University of Pavia, Italy). Individuals sampled were sexed, measured for forearm length, ear length, tragus length and tragus width (using a vernier calliper) and weighed (using a Pesola spring balance - max 50 g) as described in Arlettaz *et al.* (1991). Since 2005 wing span has also been measured (using a measuring tape). All bats were released unharmed at their capture site once they had been ringed and the measurements had been taken.

Other data sets included for comparison include *M. punicus* individuals from Sardinia (provided by M. Mucedda and M. Ruedi), Corsica (provided by G. Beuneux and M. Ruedi) and Morocco (provided by M. Ruedi and collected by R. Arlettaz).

SPSS v.13.0 was used to perform the statistical analyses and produce graphical representations of data sets. The results presented in this manuscript are given in millimetres for forearm length, ear length, tragus length, tragus width and wing span. Weight is given in grams. All measurements included in the tables are written to one decimal place due to equipment limitations. Before carrying out any statistical test, all parameters were tested for normality using the Kolmogorov-Smirnov test at p-value = 0.05 to ensure that the distribution was normal and none of the data was skewed.

The descriptive statistics carried out for six morphometric variables investigated in Maltese samples of *M. punicus* (Table 1) include the mean, a 95% confidence interval for the mean, standard deviation, minimum and

maximum. The 95% confidence interval for the mean better covers the range for the true value of the mean with a strong significance and so helps to reduce the effect of sampling error and instrument limitations. The number of males and females are included because some of the variables are sexually dimorphic and a true species average can only be obtained with a 1:1 (50%) ratio between males and females. Box plots (Fig. 1) were also drawn up to showing the means and ranges of these six morphometric variables investigated. A Pearson Correlation matrix (Table 2) was included for *M. punicus* in Malta where a two-tailed significant p-value of 0.05 was used.

Table 1
Descriptive statistics for six morphometric variables investigated in *Myotis punicus* individuals from Malta. The number of males and females sampled, mean, standard deviation and range are given for each morphometric variable.

Character	N		Mean	95% Confidence Interval for Mean		St. Dev.	Min.	Max.
	M	F		Lower	Upper			
Forearm Length	126	100	60.0	59.7	60.2	1.7	54.5	65.0
Ear Length	82	56	26.2	25.9	26.5	2.0	21.0	30.9
Weight	48	30	21.8	21.4	22.3	1.9	17.1	29.0
Wing Span	24	9	383.6	379.9	387.3	10.5	361.0	409.0
Tragus Length	56	38	11.2	11.0	11.5	1.1	9.2	16.5
Tragus Width	17	16	3.4	3.3	3.6	0.4	2.9	4.6

Table 2
Pearson Correlation matrix for *Myotis punicus* individuals from Malta showing 2-tailed significance for six morphometric variables and sex. Sex was strongly correlated with forearm length, ear length and borderline for wing span indicating sexual dimorphism.

	Sex	Forearm Length	Ear Length	Tragus Length	Wing Span	Weight
Forearm Length	0.0000	.				
Ear Length	0.0059	0.0006	.			
Tragus Length	0.1348	0.7417	0.0132	.		
Wing Span	0.0524	0.0017	0.0030	0.5756	.	
Weight	0.1914	0.0013	0.0095	0.6824	0.1376	.
Tragus Width	0.7390	0.5051	0.6192	0.3795	N/A	0.5101

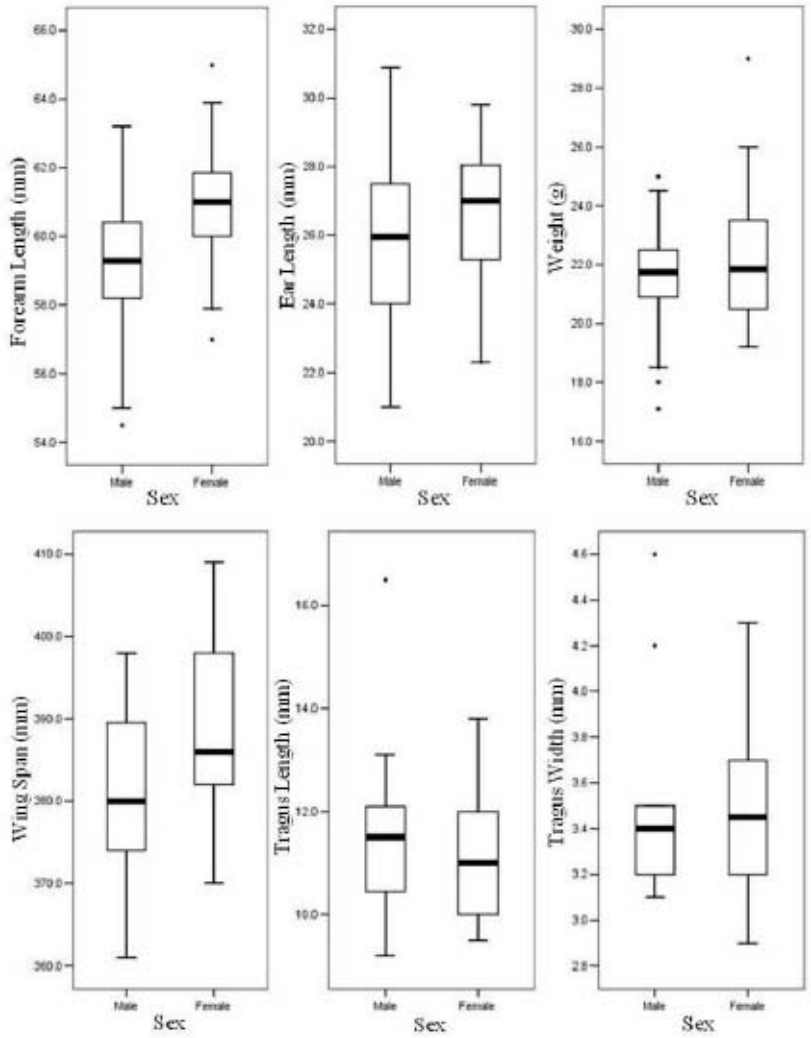

Fig. 1 — Box plots showing the means and ranges for six morphometric variables investigated in *Myotis punicus* individuals from Malta showing sexual dimorphism for forearm length, ear length and wing span with female averages being higher.

For comparison between the *M. punicus* populations of the various regions (Malta, Corsica, Sardinia and Morocco) there were only two external morphometric parameters of all four datasets recorded, namely forearm length and ear length. Weight was available for only three of these datasets. The descriptive statistics carried out for forearm length, ear length and weight in the four datasets of *M. punicus* (Table 3) include the mean, 95% confidence

Table 3
Descriptive Statistics for forearm length, ear length and weight for *Myotis punicus* individuals from Malta and a grouping of individual from Corsica, Sardinia and Morocco (except for weight). The location, number of individuals sampled, mean, standard deviation and range are given for each morphometric variable.

Character	Location	N	Mean	95% Confidence Interval for Mean		St. Dev.	Min.	Max.
				Lower	Upper			
Forearm Length	Malta	226	60.0	59.7	60.2	1.7	54.5	65.0
	Corsica, Sardinia, Morocco	466	59.5	59.4	59.7	1.7	53.8	64.5
Ear Length	Malta	138	26.2	25.9	26.5	2.0	21.0	30.9
	Corsica, Sardinia, Morocco	337	26.2	26.1	26.3	0.8	24.0	28.3
Weight	Malta	78	21.8	21.4	22.3	1.9	17.1	29.0
	Corsica, Sardinia	179	24.3	18.5	31.5	2.5	18.5	31.5

interval for the mean, standard deviation, minimum and maximum. A scatter plot of forearm length against ear length (Fig. 2) was presented with the datasets for Corsica, Sardinia and Morocco grouped as one and the dataset for Malta on its own.

RESULTS

Analysis of the Maltese M. punicus *population data*

The descriptive statistics for the Maltese population (Table 1) indicate that overall a slightly larger proportion of males was sampled. The 95% Confidence Interval indicates that the mean values are reliable and the true value of the mean is within less than 1 mm for all morphological characters with the exception of wing span which covers a much larger scale and shows the true mean is within a range of 7 cm. Forearm and ear length in the Maltese population were found to cover broader ranges than those listed for this species in DIETZ & von HELVERSEN (2004).

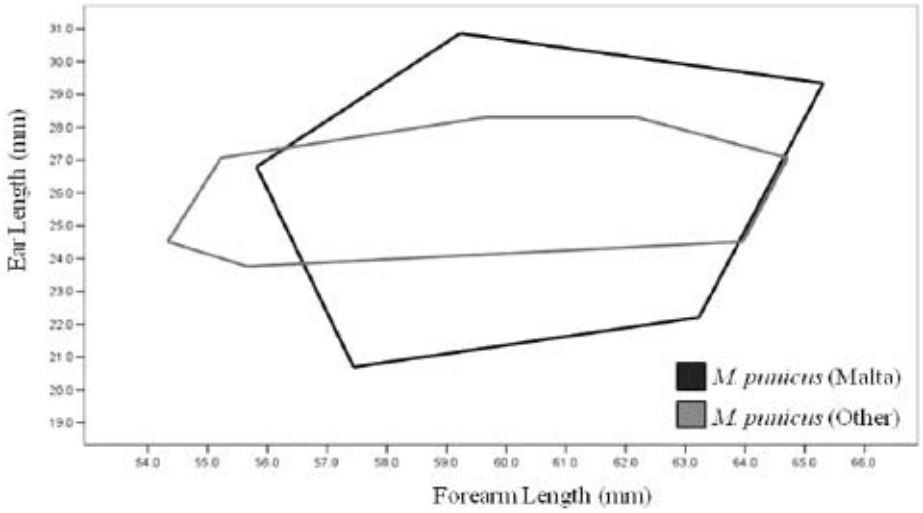

Fig. 2 — Scatter plot showing the area covered by forearm length against ear length for *Myotis punicus* individuals from Malta and a grouping of individual from Corsica, Sardinia and Morocco.

Box plots (Fig. 1) for forearm length, ear length and wing span show that the averages for females were significantly larger than males while weight, tragus length and tragus width did not show any significant difference.

The Pearson Correlation matrix (Table 2) demonstrated sexual dimorphism for forearm length, ear length and possibly wing span (borderline) since there is a strong correlation of these characters to sex.

Forearm length was found to be correlated with ear length, wing span and weight. It was expected that forearm length would be strongly correlated to wing span since the latter is directly dependent on the former.

Ear length was found to be correlated with tragus length, wing span and weight. It was expected that ear length would be strongly correlated to both tragus length and width but tragus width seems to be completely independent. No correlation value could be calculated for tragus width with wing span because none of the individuals sampled for wing span were also sampled for tragus width.

The strong correlation between weight and forearm length as well as ear length was the most noteworthy find. Although individuals that are overall larger would be expected to be heavier there might be other reasons why only these two morphological characters such as a link to manoeuvrability or hunting efficiency. These two abilities are proposed because wing span did not show correlation to weight so it was not just a matter of size. Since ear length and forearm length have strong correlation with each other it is probable that

one of these morphological characters is the driving factor and the other is only an indirect correlation.

Comparison between the M. punicus *populations of the various regions*

The comparison of descriptive statistics between datasets (Table 3) indicated that the mean for both forearm and ear length is identical within the datasets. On the other hand the mean weight for the populations of Corsica and Sardinia had a higher average due to the larger proportion of females sampled in these datasets. The standard deviation confirmed a similar spread in the data for forearm length and to some extent weight in both datasets but ear length showed a much higher variance in the Maltese dataset than the combined group (of Corsica, Sardinia and Morocco). The ranges covered by the data also conform to this pattern, where forearm length and weight ranges between the datasets were more concordant than the range obtained for ear length, which in the Maltese dataset covered twice the range of the combined dataset (of Corsica, Sardinia and Morocco).

The scatter plot (Fig. 2) gives a graphical representation of the pattern observed in the descriptive statistics that while the Maltese dataset covers a somewhat narrower range for forearm length than the combined dataset (of Corsica, Sardinia and Morocco), it extends over a much wider range for ear length.

DISCUSSION

Overall, the results presented indicate a shift in the ranges of a number of morphometric characters. Various authors have commented about the discrepancy in the range of external morphometrics variables between countries with insular populations usually presenting larger values than continental ones due to adaptation of the morphological characters to insular conditions (KOWALSKI and RZEBIK-KOWALSKA, 1991; BENDA & HORÁČEK, 1995; MUCEDDA & NUVOLI, 2000; BEUNEUX, 2004; EVIN *et al.*, 2008). On the other hand, increased pressures of intraspecific competition and resource limitation generally tend to promote dwarf variants in insular bat species (KRZANOWSKI, 1967; LOMOLINO, 2005).

The hypothesis proposed by the authors that intraspecific competition resulting from habitat destruction and reduced food resources has pushed *M. punicus* to expand its ecological niche (niche invasion - sensu SCHLUTER, 2000) aided moreover by the local extinction of *R. ferrumequinum* on the Maltese Islands seems to be supported by the data collected for a number of

morphometric variables although it is not known which of the proposed reasons is the main driving force.

Two aspects of the natural history of the *M. punicus* that most probably play a part in this process are: *M. punicus* does not generally cross water barriers (BIOLLAZ *et al.*, 2010). Second, *M. punicus* is an opportunistic, generalist predator. This is observed in the different proportions of insect groups making up the diet of *M. punicus* in Malta as compared to for example Corsica. The diet of the Maltese population is heavily dependent on Orthoptera (65%) with Lepidoptera and Coleoptera (20% and 15% respectively) making up the remainder (BORG, 1998), while in Corsica, Lepidoptera and Coleoptera cover a greater proportion and Orthoptera make up only 36% of the diet (BEUNEUX, 2004).

The increased use of pesticides on agricultural land with the increased population demand has kept the populations of such insect groups well in check, which has lead to reduced food resources for bats and as a result have brought about increased intraspecific resource competition, which has promoted some individuals to utilise the vacant food niche or feed on prey at the boundary of the ancestral niche.

Morphological differences are known to be partly the result of phenotypic plasticity, such that environmental variables directly influence phenotypes but do not translate into heritable trait variation (STEARNS, 1989). The authors do not yet know whether the morphological differences presented here represent a heritable or plastic change although the first author is in the process of confirming this through genetic analysis.

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