Published by Associazione Teriologica Italiana
Hystrix, the Italian Journal of Mammalogy
Volume 24 (2): 174–176, 2013
Available online at:
http://www.italian-journal-of-mammalogy.it/article/view/8728/pdf
doi:10.4404/hystrix-24.2-8728

Research Article

The diet of four species of horseshoe bat (Chiroptera: Rhinolophidae) in a mountainous region of Algeria: evidence for gleaning

Mourad Ahmim[a,*], Aissa Moali[a]

[a]*Laboratory of Ecology and Environment, Department of biological sciences of environment, Faculty of Nature Sciences and Life, Abderrahmane Mira University, Bejaia, Algeria*

Keywords:
diet
Rhinolophidae
Northern Algeria

Article history:
Received: 5 January 2013
Accepted: 11 January 2013

Acknowledgements
The authors are very grateful to Christian Erard, Jiri Gaisler, Virginie Mézan-Muxart, Paul Racey, Danilo Russo and to two anonymous referees for their critical revision of our manuscript.

Abstract

We analyzed the diet of four rhinolophids (*Rhinolophus ferrumequinum*, *R. hipposideros*, *R. euryale* and *R. blasii*) in the region of Kabylia Babors, in northern Algeria. Between March 2007 and January 2008 we sampled droppings at ten sites and carried out a morphological identification of prey remains. Three main groups of Arthropoda (Insecta, Chilopoda and Araneida) were preyed upon but frequencies varied across species. The insect prey most frequently preyed upon by *R. ferrumequinum* are Diptera (34.56%), mainly including Culicidae (10.40%), Chironomidae/Ceratopogonidae (10.94%) and Tipulidae (4.28%), and also Lepidoptera (24.13%). In *R. hipposideros* droppings we found Diptera (41.58%) , Chironomidae/Ceratopogonidae (9.68%) and Tipulidae (6.45%). Also common were Lepidoptera (moths; 21.14%) and Hemiptera (11.68%).

R.euryale ate mainly Diptera (29.00%), Chironomidae/Ceratopogonidae (7.14%) and Tipulidae (5.71%). The order Lepidoptera (moths) was also well represented (19.08%). *R. blasii* preyed on two groups of Arthropoda: Insecta (96.87%) and Chilopoda (4.34%). The most consumed insect prey was Diptera (37.50%), mainly Chironomidae/Ceratopogonidae (9.38%), Culicidae, Anisopodidae and Sphaeroceridae (6.25%). The order Trichoptera was also well represented in its diet (15.63%) and Lepidoptera accounted for 12.50%. The most interesting aspect of this study was that Chilopoda appeared in the diet of all species and that, albeit rarely, *R. ferrumequinum* also ate spiders. This result suggests that all species could glean prey from substrate, most probably as a strategy to better exploit the open habitats typical of the study area.

Introduction

In Algeria, bats in the family Rhinolophidae are present with six species: *Rhinolophus blasii* (Peters, 1866), *R. clivosus* (Cretzchmar, 1828), *R. euryale* (Blasius, 1853), *R. ferrumequinum* (Schreiber, 1774), *R. hipposideros* (Bechstein, 1800) and *R. mehelyi* (Matschie, 1901). Four of these species are listed in the IUCN Red List with the LC (least concern) status for *R. ferrumequinum* and *R. hipposideros* (Aulagnier et al., 2008; Jacobs et al., 2008), and the statuses of the two other species are respectively NT (near threatened) for *R.euryale* (Hutson et al., 2008), and Vu (vulnerable) for *R. blasii* (Hutson et al., 2007).

Nothing is known about the foraging ecology and diet of these species in Algeria. This knowledge is needed to obtain a more comprehensive picture of the ecology of such species outside the European range, where most available studies have been carried out, and develop locally tailored conservation strategies. To address this goal, we investigated the diet of the four species whose populations are clearly decreasing (*R. ferrumequinum*, *R. hipposideros*, *R. euryale* and *R. blasii*) presenting the results of the analysis of a one-year collection of droppings.

Material and methods

Study area

Our study was conducted in the East of the Great Kabylia (Kabylia of Djurdjura), in northeastern Algeria. This is a mountainous area with an average elevation of 1000 m a.s.l., rising to the mountains of Jebel Babor (2004 m a.s.l.) and Jebel Tababor (1969 m a.s.l.). The topography of the region is very rugged, with slopes often exceeding 25° (Bellatreche, 1994). Our study area lies between the districts of Bejaia (36° 49'N - 5° 3'E) and Jijel (36° 47'N - 5° 46'E). It is a coastal region bordered by the the Soummam river and dominated by farmland and human settlements. We collected droppings at ten roosts: the cave of Boublatane in Jijel, the caves of Taâssast, Aokas, four caves at Boukhiama, the cave of the Elephants, the ruins of Fort Lemercier, and an old castle named Château de la Comtesse, in Bejaia.

Sampling of droppings

We collected droppings at all sites between March 2007 and January 2008 at intervals of one or two weeks. We placed a sheet of paper underneath the colony to collect all droppings, but only ten of them were selected each time for subsequent analyses.

For analysis, the droppings were soaked for $\geq$1 hour in 70% ethanol and then teased apart under a 40$\times$10 binocular microscope. We identified prey remains according to Shiel et al. (1997).

The results were expressed as percent frequency of occurrence, i.e. the number of pellets which contained a given taxon, divided by the total number of pellets, multiplied by 100 (e.g. Vaughan 1997; Del Vaglio et al. 2011).

Results

We analysed 866 droppings, 489 for *R.ferrumequinum*, 214 for *R.hipposideros*, and 131 and 32 for *R.euryale* and *R. blasii* respectively (Tab. 1).

Prey remains belonged to 11 orders of Insecta, together with Chilopoda and Araneida (Tab. 2, Fig. 1).

Rhinolophus ferrumequinum *R. ferrumequinum* fed on three groups of arthropods: Insecta (95.31%), Chilopoda (4.49%) and Araneida (0.20%). The most frequent insect prey were Diptera

*Corresponding author
Email address: forestecolo@gmail.com (Mourad Ahmim)

Table 1 – Number of droppings per month per species for the total of sites.

Month	March	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Total
Number of sampling sessions	3	3	7	4	4	3	5	4	5	1	4	**43**
Droppings – total	20	52	25	69	28	46	105	117	118	139	147	**866**
R. ferrumequinum	10	30	10	30	14	20	70	55	50	90	110	**489**
R. hipposideros	10	10	5	20	0	20	10	42	38	29	30	**214**
R. euryale	0	12	10	10	10	6	20	10	30	18	5	**131**
R. blasii	0	0	0	9	4	0	5	10	0	2	2	**32**

(34.56%) and Lepidoptera (24.13%). Diptera included mainly Culicidae (10.40%), Chironomidae/Ceratopogonidae (10.94%) and Tipulidae (4.28%).

Rhinolophus hipposideros *R. hipposideros* fed on two groups of arthropods: Insecta (93.46%) and Chilopoda (6.54%). The most frequent prey was represented by dipterans (41.58%), mainly Culicidae (15.59%), Chironomidae/Ceratopogonidae (9.68%) and Tipulidae (6.45%). Lepidoptera also accounted for a large proportion of prey (21.1%), as well as Hemiptera (11.68%).

Rhinolophus euryale *R. euryale* too fed on two groups of arthropods: Insecta (96.19%) and Chilopoda (3.81%). The most frequent prey was represented by dipterans (29.00%), specifically Culicidae (14.29%), Chironomidae/Ceratopogonidae (7.14%) and Tipulidae (5.71%). Lepidoptera also represented a large proportion in diet (19.08%).

Rhinolophus blasii *R. blasii* preyed upon two groups of arthropods: Insecta (96.87%) and Chilopoda (3.13%). The insect prey most frequently eaten was represented by Diptera (37.5%), specifically Chironomidae/Ceratopogonidae (9.38%), Culicidae, Anisopodidae and Sphaeroceridae (6.25%). Trichoptera also were frequent (15.63%), followed by Lepidoptera.

Discussion

Rhinolophus ferrumequinum In our study, the diet of *R. ferrumequinum* consisted mainly of insects such as Diptera and Lepidoptera, and Chironomidae/Ceratopogonidae as well as members of the Culicidae family such as mosquitoes.

Besides catching prey on the wing, we found that *R. ferrumequinum* also gleans prey from substrates, because its diet included taxa which either rarely fly (e.g., Cercopedae, Aphidoidea and Dermaptera) or are ground dwellers (e.g., Chilopoda and Arachnida). As in other studies (Jones, 1990; Ransome, 1996; Jin et al., 2005) Lepidoptera were the most frequent prey.

According to previous studies *R. ferrumequinum* is more specialized than the other Rhinolophidae and consumes mainly Lepidoptera (in summer) and Coleoptera, especially *Geotrupes*, *Melolontha* and *Aphodius* (Ransome, 1996). Diptera (specially Tipulidae and Muscidae) appear among the most frequent secondary prey (Duvergé, 1996; Ransome, 1968, 1996). When possible according to local prey availability, the arthropods consumed by *R. ferrumequinum* are larger than those eaten by *R. hipposideros*. This agrees with the frequency difference found between the echolocation calls of these bats (e.g. Russo and Jones 2002 since, as shown by Gould (1955) echolocating bats tend not to catch insects smaller than the wavelength of the emitted ultrasound.

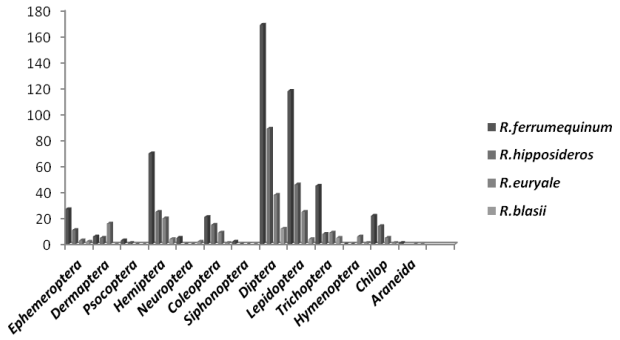

Figure 1 – Numbers of prey remains identified in the feacal pellets of Rhinolophidae of Kabylia.

In Korea, the diet of *R. ferrumequinum* frequently includes Coleoptera (30.77%), Diptera (27.38%) and Lepidoptera (13.31%). Prey types recovered also included small numbers of Hymenoptera and Neuroptera (Hyun et al., 2007).

The presence of a small proportion of spiders (0.18%) raises a number of questions, e.g., are they gleaned from the vegetation, the ground, or captured when carried in the air on by strands of silk? According to Beck (1997); McAney and Fairley (1989); McAney et al. (1991) and Pir (1994), *R. ferrumequinum* captures spiders only occasionally. The occurrence of Chilopoda strongly suggests that this bats may be able to glean prey from substrate.

Rhinolophus hipposideros In our study area *R. hipposideros* preyed most frequently upon Diptera, followed by Lepidoptera and Hemiptera. Other arthropods were only rarely eaten.

In Europe at least 12 orders and 34 families of the class of Insecta were identified in the diet of *R. hipposideros* (Roue and Barataud, 1999). As in our study, Lepidoptera are the most frequent prey: although some of them are tympanate, i.e. sensitive to ultrasound, they are still frequently captured, most probably because the species echolocation call frequencies (Russo and Jones, 2002) are much higher than the audible frequency threshold of these insects (McAney and Fairley, 1989; McAney et al., 1991; Williams et al., 2011).

Table 2 – Frequencies of occurrence of different anatomical parts of preys found in the faecal pellets of Rhinolophidae of Kabylia.

		R. ferrumequinum		*R. hipposideros*		*R. euryale*		*R. blasii*	
Class	**Order**	**Number**	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
Insecta	Ephemeroptera	27	5.52	11	5.14	3	2.29	2	6.25
	Dermaptera	6	1.22	5	2.33	16	12.21	-	-
	Psocoptera	3	0.61	1	0.46	-	-	-	-
	Hemiptera	70	14.31	25	11.68	20	18.18	4	12.50
	Neuroptera	5	1.02	-	-	-	-	2	6.25
	Coleoptera	21	4.29	15	7.00	9	6.87	1	3.13
	Siphonoptera	2	0.40	-	-	-	-	-	-
	Diptera	169	34.56	89	41.58	38	29.00	12	37.50
	Lepidoptera	118	24.13	46	21.14	25	19.08	4	12.50
	Trichoptera	45	9.20	8	3.73	9	6.87	5	15.63
	Hymenoptera	-	-	-	-	6	4.58	1	3.13
Chilopoda spp.		22	4.49	14	6.54	5	3.81	1	3.13
Arachnida	Araneida	1	0.20	-	-	-	-	-	-

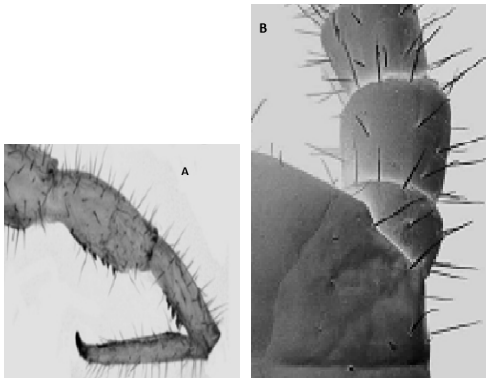

Figure 2 – Fragments of Chilopoda found in the faeces. (A: Leg; B: Part of head with antenna).

Rhinolophus euryale This bat often ate Diptera in our study area, and this order accounted for ca 29% of all prey, whereas Lepidoptera accounted for ca. 20%. This bat mostly preys on moths that are typically captured in forest habitats (Russo et al., 2002, 2005), such as Lepidoptera and Diptera, especially Tipulidae (Koselj and Krystufek, 1999; Goiti et al., 2004).

In the Basque Country, small Lepidoptera, followed by Tipulidae and Scarabeidae (*Rhizotrogus* sp.) were found to represent the most frequent prey (Goiti et al., 2004). Small Lepidoptera are especially important in the reproductive season, whereas other prey can constitute a seasonally important food resource (Goiti et al., 2008).

R. euryale seems to be better adapted to forage in cluttered habitats (Russo et al., 2005). Its aspect ratio correlates well with flight characteristics, with lower aspect ratios endowing greater manoeuvrability. Previous studies show that the bulk of the diet of this species comprised very similar prey categories, mainly Lepidoptera, and to a lesser extent Coleoptera and Neuroptera (Salsamendi et al., 2005).

Rhinolophus blasii In the diet of this species dipterans, especially Chironomidae and Ceratopogonidae, are the most represented food. Trichoptera are also frequent, probably due to occurrence of water habitats in our study area. The orders Lepidoptera and Hemiptera represent 12.5% each, the third and fourth most important prey components. Chilopoda occurred with a frequency of 3.13%

A comparison of the diet of the four Rhinolophidae studied from the region of Kabylia of Babors in the north of Algeria shows that they have broadly similar diets. There are, however, some differences. Certain insect taxa were absent from the diet of the species we studied: Hymenoptera from that of *R. ferrumequinum*, Neuropteran and Siphonoptera from that of *R. hipposideros*, Psocoptera, Neuroptera and Siphonoptera from that of *R. euryale* and Psocoptera, Dermaptera and Siphonoptera from that of *R. blasii*.

While Araneidae and Siphonoptera were eaten exclusively by *R. ferrumequinum*, the most remarkable finding is given by the occurrence of Chilopoda in the diet of all species (Fig. 2).

About the presence of Chilopoda , Siemers and Ivanova (2004) tested ground-gleaning as an additional prey-capture strategy for horseshoe bats and found that, at least in laboratory studies, only *R. blasii* shows a tendency to glean prey from the ground yet all bats studied (*R. blasii*, *R. euryale* and *R. mehelyi*) all easily took off from the ground. However, bats are known to show local spatial or temporal shifts in foraging behaviour (Russo et al., 2011) and our findings point at a locally specialized trophic niche which may well not be observed elsewhere.

Only a previous single record showed the presence of Solpugida in *R. ferrumequinum* diet (Benda et al., 2010), but in this study we show that centipedes are well represented in the diet of rhinolophids from North Africa, fully supporting the fact that these bats may glean prey from substrate.

As Siemers and Ivanova (2004) put it, the key evolutionary innovation in rhinolophids, the high duty cycle CF echolocation, facilitates flutter-detection. This powerful prey-detection system paired with manoeuvrable flight abilities apparently allow horseshoe bats to rely on a considerable behavioural flexibility in foraging and prey capture (aerial, foliage-gleaning in flight, ground-gleaning including landing) and hence in habitat use, possibly explaining the evolutionary success of the genus Rhinolophus.

References

Aulagnier S., Hutson A.M., Spitzenberger F., Juste J., Karataş A., Palmeirim J., Paunovic M., 2008. *Rhinolophus ferrumequinum*. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011(2). IUCN, Gland, Switzerland.

Beck A., 1997. Fecal analyses of european bat species. Myotis 32–33: 109–119.

Bellatreche M., 1994. Ecologie et biogeographie de l'avifaune forestière nicheuse de la Kabylie des babors, thèse, Univ. Bourgogne, France. [in French]

Benda P., Lucan R.K., Obuch J., Reiter A., Andreas M., Backor P., Bohnenstengel T., Khalil E.E., Ševcik M., Vallo P., Amr Z.S., 2010 . Bats (Mammalia: Chiroptera) of the Eastern Mediterranean and Middle East. Part 8. Bats of Jordan: fauna, ecology, echolocation, ectoparasites . Acta Soc. Zool. Bohem. 74: 185–353.

Del Vaglio M.A., Nicolau H., Bosso L., Russo D., 2011. Feeding habits of the Egyptian fruit bat *Rousettus aegyptiacus* on Cyprus island: a first assessment. Hystrix 22(2): 281–289. doi:10.4404/hystrix-22.2-4587

Duvergé P.L., 1996. Foraging activity, habitat use, development of juveniles, and diet of the greater horseshoe bat (*Rhinolophus ferrumequinum* Schreber 1774) in south-west England. Thesis Univ. Bristol, School of Biological Sciences.

Goiti U., Aihartza J.R., Garin I., 2004. Diet and prey selection in the Mediterranean horseshoe bat *Rhinolophus euryale*s (Chiroptera, Rhinolophidae) during the pre-breeding season. Mammalia 68(4): 397–402.

Goiti U., Garin I., Almenar D., Salsamendi E., Aihartza J., 2008 . Foraging by Mediterranean Horseshoe Bats (*Rhinolophus euryale*) in Relation to Prey Distribution and Edge . Habitat. Journal of Mammalogy 89(2): 493–502.

Gould E., 1955. The feeding efficiency of insectivorous bats. Journal of Mammalogy 36: 399–407.

Hutson A.M., Spitzenberger F., Juste J., Aulagnier S., Alcaldé J.T., Palmeirim J., Paunovic M., Karataş A., 2008. *Rhinolophus euryale*s. IUCN Red List of Threatened Species. Version 2011(2). IUCN, Gland, Switzerland.

Hutson T., Spitzenberger F., Aulagnier S., Nagy Z., 2007. *Rhinolophus blasii*. IUCN Red List of Threatened Species. Version 2011(2). IUCN, Gland, Switzerland.

Hyun K., Chil S., Chil J., Yoo J., 2007. Variation in the diet of the greater horseshoe bat (*Rhinolophus ferrumequinum*). Dept. of Biology and The Korea Institution of Ornithology, Kyung-Hee University. Japan.

Jacobs D., Cotterill F.P.D., Taylor P.J., Aulagnier S., Juste J., Spitzenberger F., Hutson A.M., 2008. *Rhinolophus hipposideros*. IUCN Red List of Threatened Species. Version 2011(2). IUCN, Gland, Switzerland.

Jin L., Feng J., Sun K., Liu Y., Wu L., Li Z., Zhang X., 2005. Foraging strategies in the greater horseshoe bat (*Rhinolophus ferrumequinum*) on Lepidoptera in summer. Chinese Science Bulletin 50(14) : 1477–1482.

Jones G., 1990. Prey selection by the greater horseshoe bat (*Rhinolophus ferrumequinum*) optimal foraging by echolocation. Journal of Animal Ecology 59: 587–607.

Kervyn T., 1998. Methodes de determination du regime alimentaire des Chiropteres insectivores. Arvicola 1998() Actes "Amiens 97": 53–56. [in French]

Koselj K., Krystufek B., 1999. Diet of the Mediterranean horseshoe bat *Rhinolophus euryale* in south-eastern Slovenia. Bat Res. News 40 (3): 121.

McAney C., Shiel Sullivan C., Fairley J., 1991. The analysis of bat droppings. The Mammal Society. Occ. Publ. 14. London.

McAney C., Fairley J., 1989. Analysis of the diet of the lesser horseshoe bat *Rhinolophus hipposideros* in the West of Ireland. Journal of Zoology 217(3): 491–498.

Pir J., 1994. Etho-Öchologische Untersuchungen einer wochenstubenkolonie der Grossen Hufeisennase (*Rhinolophus ferrumequinum* Schreber, 1774) in Luxemburg. Dipl. Arbeit. Justus–Liebig–Univ., Giessen. 60–75. [in German]

Ransome R.D., 1996. The management of feeding areas for the greater horseshoe bats. English Nature Res. Rep. 174: 1–74.

Ransome R.D., 1968. The distribution of the greater horseshoe bat, *Rhinolophus ferrumequinum* during hibernation, in relation to environmental factors. Journal of Zoology (London) 154: 77–112.

Roue S.Y., Barataud M., 1999. Habitats et activité de chasse des Chiroptéres menacés en Europe en vue d'une gestion conservatrice. le Rhinolophe Vol. Spec. 2: 136. [in French]

Russo D., Jones G., 2002. Identification of twenty–two bat species (Mammalia: Chiroptera) from Italy by analysis of time-expanded recordings of echolocation calls. Journal of Zoology (London) 258: 91–103.

Russo D., Jones G., Migliozzi A., 2002. Habitat selection by the Mediterranean horseshoe bat, *Rhinolophus euryale* (Chiroptera: Rhinolophidae) in a rural area of southern Italy and implications for conservation. Biological Conservation 107: 71–81.

Russo D., Almenar D., Aihartza J., Goiti U.,Salsamendi E., Garin I., 2005. Habitat selection in sympatric *Rhinolophus mehelyi* and *R. euryale* (Chiroptera: Rhinolophidae). Journal of Zoology (London) 266: 327–332.

Russo D., Maglio G., Rainho A., Meyer C.F., Palmeirim J., 2011. Out of the dark: diurnal activity in the bat *Hipposideros ruber* on São Tomé island (West Africa). Mammalian Biology 76: 701–708.

Salsamendi E., Aihartza J., Goiti J., Almenar D., Garin I., 2005. Echolocation calls and morphology in the Mehelyi's (*Rhinolophus melelyi*) and Mediterranean (*R.euryale*) horseshoe bats: implication for resource of partitioning. Hystrix 16(2): 149–158. doi: 10.4404/hystrix-16.2-4353

Shiel C., Mcaney C., Sullivan C., Fairley J., 1997. Identification of Arthropod Fragments in Bat Droppings. Occ. Pub. 17. The Mammal Society.

Siemers B.M., Ivanova T., 2004. Ground gleaning in horseshoe bats: comparative evidence from *Rhinolophus blasii*, *R. euryale* and *R. mehelyi*. Behav. Ecol. Sociobiol. 56: 464–471.

Vaughan N., 1997. The diets of British bats (Chiroptera). Mammal. Rev. 27(2): 77–94.

Williams C., Salter L., Jones G., 2011. The winter diet of the lesser horseshoe bat (*Rhinolophus hipposideros*) in Britain and Ireland. Hystrix 22(1): 159–166. 10.4404/hystrix-22.1-4498

Associate Editor: D. Russo