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Original investigation

Have introduced fish initiated piscivory among the long-fingered bat?

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Abstract

During the winter of 2003–2004 feces were collected from a winter colony of the long-fingered bat (*Myotis capaccinii*) in the Hazorea cave (north-west Israel). Of the 1913 feces that were examined, 234 contained scales of *Gambusia affinis* – a small fish that had been introduced to Israel around 1920 in order to control mosquito larvae. The remains of spiders and five insect orders were also represented in the feces. This is the first report of a piscivorous bat in the Middle East and the first finding of fish remains in the feces of *M. capaccinii*. The findings show that in the north of Israel this species does not hibernate but remains active throughout the winter. It appears that the consumption of *G. affinis* reflects a change in the diet of these bats from insectivory to semi-piscivory.

Key words: *Myotis capaccinii*, *Gambusia affinis*, Israel, piscivory

Introduction

Piscivory as the main feeding pattern in bats is known from two species: *Noctilio leporinus* and *Myotis vivesi* (Bloedel 1955; Reeder and Norris 1954; Kalko et al. 1994). However, feeding partly on fish by insectivorous bats is known from several other species of the genus *Myotis*. Fish remains were found in *M. daubentoni* feces in France (Brosset and Delmare 1966), and this species is also known to pick up small fish from the water in captivity (Siemers et al. 2001a). Fecal analysis of *M. ricketti* from China confirms that this species too feeds partly on fish (Ma et al. 2003). Behavioral experiments suggest that the three species of European trawling *Myotis* (i.e. *M. capaccinii, M. daubentoni* and *M. dasycneme*) can take objects from smooth surfaces (Siemers et al. 2001b). Finally, fish scales were recently found in the feces of four free-living *M. capaccinii* females in Spain, but the fish were never identified (Aihartza et al. 2003).

The long-fingered bat, *M. capaccinii* (Vespertilionidae) is a common bat near aquatic environments in the northern part of Israel (Shalmon et al. 1993). This small insectivorous bat (6–10 g) is found in the Mediterranean region of Europe and northwest Africa, in Asia Minor, and in the Middle East from Israel and Lebanon to Iran and Uzbekistan

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(Corbet 1978). *M. capaccinii* is known as a 'trawling' bat that forages close to the water surface, seizing insects from both above and off the water surface, similar to other trawling bats in its subgenus (Kalko 1990; Siemers et al. 2001b).

The aim of this study was to investigate the diet of a winter colony of *M. capaccinii*, in order to determine whether piscivory exists in this species in Israel. Should such a phenomenon be found, our secondary objective was to estimate the proportion of fish and its species in the bats' diet during winter.

Material and methods

Study site

The study was conducted in the Hazorea cave (Kibbutz Hazorea, north-west Israel 32°40N 35°05E, about 50 m a.s.l.). This man-made cave is located 800 m from the Kibbutz Hazorea fisheries ponds. *M. capaccinii* exclusively inhabited the cave from the second week of November 2003 to the third week of January 2004. During this period we visited the cave six times. Twice (in November and January) bats were captured by hand net, sexed, weighed (by Pesola spring balance to an accuracy of 0.1 g), forearm measured (to an accuracy of 1 mm), and released. In order to estimate colony size, we counted the bats emerging from the cave entrance at dusk, at the beginning, middle and end of the research period.

Ambient temperature and humidity inside the cave were recorded throughout the study period every 16 min using an HOBO data logger (Onset Computer Corporation), and meteorological data were received from Ein Hashofet meteorological station (http://www.mop-zafon.org.il/).

Feces collection and analysis

Four times during the study period we positioned a polyethylene sheet (1.5 × 1.2 m) on the cave floor under the bat colony in order to collect feces. The sheet was placed one afternoon, removed 7–25 days later and replaced by a new one. Feces were dried at room temperature for 24 h and each one was later examined under a binocular microscope for identification of fish scales. Feces that contained fish scales were separated from those that contained only insect remains. For scale analysis, we softened the feces with 70% ethanol and separated the scales and bones. We found only a few fish bones, which could not be identified because of their small size and bad condition. The feces that contained fish scales had almost no insect parts. The fish scales were compared under a microscope to scales taken from fish caught in the Hazorea fisheries ponds and identified to species level (during winter the ponds are densely inhabited by several different species of small Cyprinids, as well as by *Gambusia affinis*).

For insect remains, we analyzed the contents of 200 feces, 50 feces from each visit, studying each individually under a binocular microscope (× 10, × 20) and identifying its contents to order, family or genus level. We calculated the frequency of insects found in the feces and the volume of each order in them (Whitaker 1988). Feces that contained fragments too small for identification or just digested material were marked as unidentified.

Results

Colony size

Mean colony size was 280 bats (SD = 58). Sex ratio among the 20 bats caught and sexed was 1:1. Mean body mass decreased significantly from 9.1 g (SD = 0.55, $n = 7$) in November to 7.4 g (SD = 0.69, $n = 13$) in January (*t*-test $P < 0.001$, $t = 5.477$), and there was no significant difference in mass between males and females (*t*-test $P = 0.95$, $t = 0.063$). Temperature decreased gradually during the study period from minimum of 13.2 °C outside and 15.2 °C inside the cave in mid-November until reaching a minimum of 5 °C outside and 10 °C inside the cave during the last part of December, but bats remained active throughout this period and emerged each night. None were found hibernating in the cave.

Fecal content

Of the 1913 feces examined from four periods during the research, 234 contained fish scales and bones (Tab. 1). All the samples had a strong fish odor. All of the fish scales belonged to *Gambusia affinis*. This fish was introduced into Israel from North America around 1920 in order to control mosquitoes, since it preys on mosquito larva (Goren and Ortal 1999). Today, *Gambusia* is very common in fisheries ponds, lakes and cisterns in

Table 1. Dates and number of feces collected and the proportion of feces with fish scales

Period	Number of feces that contained		Percentage of feces that contained scales (%)
	Scales	No scales	
10–21 November 2003	32	400	7.4
22–29 November 2003	40	229	14.8
30 November – 25 December 2003	12	560	2.0
26 December – 20 January 2004	150	490	23.4

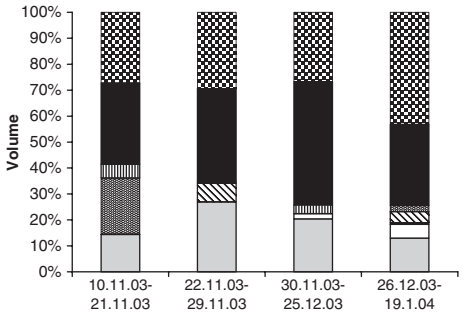

Fig. 1. Percentage volume of insect orders and arachnidae found in feces of *Myotis capaccinii* that were collected at four different periods: ⊠ Heteroptera, ■ Diptera, ▥ Hymenoptera, ▨ Coleoptera, ▧ Lepidoptera, ⊡ Ephemeroptera, □ Arachnidae, ▫ Unidentified.

northern Israel. This fish forages for mosquito larvae in the upper layer of the water and is often found at the edge of the pond, where the larvae accumulate according to the direction of the wind (M. Goren, personal communication).

Six orders of insects and arachnids were also represented in the bat feces (Fig. 1). In the first three samples we took, the most common insect group were Dipterans (almost exclusively Chironomidae). "Water boatmen's" (Corixidae-Heteroptera) were most common in January and were the only family found amongst the heteropterans, these insects are usually found beneath the water surface but can also leap out of the water and fly. Coleopteran parts were found mostly in the first sample. The high proportion of unidentified parts in the feces during the second period of the study may indicate that the bats were feeding either on soft-shelled insects, which do not leave chitin remains, or on a fish that does not leave traces of scales or bones (Siemers et al. 2001a). The feces also contained hair and parasite remains (mites and parasite flies) probably accumulated during grooming and cleaning activities of the bats.

Discussion

Myotis capaccinii is known as a trawling bat that feeds on insects from the water surface (Kalko 1990; Siemers et al. 2001b). Our findings reveal that in our study area, during the winter, fish form a large proportion of the bat's diet. This is the first report of a piscivorous bat from the Middle East, and also the first evaluation of fish proportion in the diet of this species. Since a high fraction of digested material without chitin tracts was found in the bat feces, we suspect that our findings are an underestimation of the true proportion of fish in the *M. capaccinii* diet. This assumption is supported by Siemers et al. (2001a) who reported that fish scales and bones were barely found in captive *M. daubentoni* feces after it was fed about 30 small fish, and it is therefore reasonable to assume that much of the unidentified material that we found was fish remains. This assumption is also supported by the fact that all of the examined bats droppings, even those that did not contain any scales, had strong fish odor.

In medium latitudes preying on fish can be very useful or even essential in the winter, when insect activity is low. For example, the piscivorous bat *N. leporinus* in Puerto Rico preys on both fish and insects. However, in

the dry season (February–March), when insects are less common, it feeds mostly on fish (Brooke 1994). We found the highest level of fish scales in the bat feces during the coldest period of the study (from the end of December until mid-January), when the bats remained active and did not hibernate (despite the low temperatures both inside and outside the cave). The consumption of fish, which have higher nutritional value than insects (Kalko et al. 1998), during this period could explain this observed avoidance of hibernation.

Wind velocity can also influence the bats' ability to prey on fish. Strong winds create ripples on the water surface, a situation in which it is hard for the bats to detect the echolocation "glints" of their prey. During 2 weeks in the third period of the research the daily average wind velocity was high (more than 3.5 m/s), whereas from the beginning of January (fourth period) there were few days with no wind at all. This finding can help to explain the high frequency of scales in the bats' droppings during the fourth period.

The low variability of insect orders in the bat diet may reflect the low diversity and abundance of insects during the winter in this area. The Coleopteran remains (probably from the same species but not to be identified) that were found mostly during the first days that the bats inhabited the cave, suggests that the bats had fed on these beetles during migration, or during the course of changing their foraging area. Since food passage time through the digestive tract of insectivorous bats is known to be rapid (Buchler 1975), the remains from a different foraging area can appear in the bats' feces only on the first day after arriving at a different area.

Novick and Dale (1971) compared between the skills of the fishing bats *N. leporinus* and *M. vivesi* and the trawling bats of the subgenus *Leuconoe*, all of which have large specialized feet, long fingers and similar foraging behavior. In their note Novick and Dale (1971) consider these features to be an adaptation for catching insects with their feet. We suggest that the consumption of *G. affinis* – a newly introduced fish species in Israel – indicates that *M. capaccinii* possesses the morphological adaptation and "skills" to catch fish, but has only recently begun to use them for this purpose in our study area.

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Zusammenfassung

Hat eine eingeführte Fischart Langfussfledermäuse zum Fischfang animiert?

Während des Winters 2003/2004 wurden in einem Winterquartier der Langfussfledermaus (*Myotis capaccinii*) in der Hazorea-Höhle (Nord-West Israel) Kotproben gesammelt. Von den 1913 untersuchten Pellets enthielten 234 Schuppen von *Gambusia affinis* – einem kleinen Fisch, der 1920 zur Eindämmung von Mückenlarven in Israel eingeführt wurde. Überreste von Spinnen und fünf Insektenordnungen wurden ebenfalls in den Kotproben gefunden. Dies ist der erste Bericht über eine piscivore Fledermaus im Nahen Osten und der erste Nachweis von Fisch-Überresten im Kot von *M. capaccinii*. Die Ergebnisse zeigen, daß diese Art im Norden von Israel auch im Winter aktiv ist und keinen Winterschlaf hält. Der Verzehr von *G. affinis* scheint einen Übergang von insektivorer zu semi-piscivorer Ernährung wiederzuspiegeln.

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