

Frugivory of the Stone Marten (*Martes foina* Erxl.) in Bulgaria – a review from an urban perspective

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Abstract. The present study reviewed frugivory characteristics of the Stone Marten (*Martes foina* Erxleben, 1777) in Bulgaria with special reference to cultivated plants. A total of six studies were compiled, which showed that nine species fruits (eight species of them were cultivated) and 17 genus/family-level-identified fruits (six genera of them were cultivated) were consumed by the marten.

Key words: cultivated plant, diet, urban carnivore

Introduction

Human-wildlife conflicts are increasing with the expansion of human activities and urban development. Understanding how carnivores can adapt to urban environment is rapidly important for reducing human-wildlife conflict (Gehrt 2004). The Stone Marten (*Martes foina* Erxleben, 1777) is an omnivorous feeder, one of the few mustelids that can inhabit urbanised environments (Herr 2010). It is suggested that martens' flexible and opportunistic foraging behaviour could facilitate their success in human-modified landscapes (Hisano *et al.* 2016).

Located on the Balkan Peninsula, Bulgaria is one of the southern populations of the Stone Marten's distribution (Nagai *et al.* 2012). Dietary researches into the martens in Bulgaria is recently increasing, which provides an opportunity to summarise fruit species consumed by the Stone Marten in Bulgaria (cf. Hisano & Deguchi 2017). This information can help us understand marten's adaptability to urbanised environments in terms of feeding ecology (Hisano *et al.* 2016). Here I review frugivory characteristics of the Stone Marten in Bulgaria with special reference to human-subsidised fruits.

The literature on food composition of the Stone Marten written in English (as of 2017) was browsed, using Google Scholar (<https://scholar.google.com>). Different combinations of keywords were entered for the literature search: "Beech Marten", "Bulgaria", "*Martes foina*", "diet", "food", and "Stone Marten". Among the browsed studies, those did not have information on foraged fruit taxa were not subject to review. For the convenience, seeds of forbs/graminoids were categorised into 'fruits' although they were not actually berries. Potentially cultivated plants (e.g., from orchards, farms, gardens, roadsides; *sensu* Hisano *et al.* 2016) were marked based on the reviewed literature and author's prior knowledge. It is notable that fruit taxa in Petrov *et al.* (2015, 2016) were reported as consumed by *Martes* spp. (Stone Marten and Pine Marten (*Martes martes* Linnaeus, 1758)) due to unclarity of the faeces origin. However, pine martens rarely occur human-modified landscapes in Bulgaria, usually inhabiting highlands without human occupation (Popov & Sedefchev 2003; Hisano *et al.* 2016; Petrov *et al.* 2016), and this could not affect the compilation of cultivated fruits, the main focus of this review.

Results

A total of six studies from both natural and human-modified areas in Bulgaria were reviewed (Table 1). In these studies, fruits of nine (five trees and four herbs) plants were identified to species level, and 17 (14 trees and three herbs) plants respectively to genus/family level, as marten's food (Table 2). Among them, eight species-identified fruits and six genus-identified fruits were considered as cultivated plants (Table 2).

Table 1. A summary of studies on the Stone Marten in Bulgaria reporting its fruit consumption.

Source	Region ^a	Habitat type	Study period	Method ^b	Sample size ^c
Georgiev (2013)	C	Urban	Jun 2005-Dec 2006	F	67
Georgiev & Raichev (2009)	SE	Forest	Apr 2006	F	47
Petrov <i>et al.</i> (2015)	S, SW	Forest	Jun-Aug 2011-2014	F	139
Petrov <i>et al.</i> (2016)	W, SW	Forest	Jan-Dec 2010-2014	F	-
Hisano <i>et al.</i> (2013)	C	Arable land, forest	Nov-Mar 1997-2009	S	50
Hisano <i>et al.</i> (2016)	C	Urban, forest	May-Aug 2013	F	310

^a C: central Bulgaria, S: southern Bulgaria, SE: south-eastern Bulgaria, SW: south-western Bulgaria.

^b F: faecal analysis, S: stomach contents analysis.

^c Information of sample size for Petrov *et al.* (2016) was not available.

Discussion

The present review shows that the Stone Marten in Bulgaria foraged various species of fruits. Note that, however, it is assumable that seeds of Pinaceae and Poaceae might have been foraged by chance while foraging for other foods because they could not be of nutrient importance for martens. It is remarkable that cultivated plants accounted for a great proportion of the consumed fruits (88.9 % of those identified to species level; 35.3 % of those identified to genus level). The cultivated fruits are obtained from orchards (e.g., *Cerasus*, *Prunus*, *Malus*), farms/gardens (e.g., Solanaceae, *Fragaria*), or roadsides (e.g., *Morus*). Therefore, by showing various types of cultivated fruits consumed by the marten, the present review confirms the marten's utilisation of cultivated fruits in human-modified habitats (Hisano *et al.* 2016). This suggests generality of its flexible diet across the country although we could not quantitatively assess this without metrics of frequency. It should also be noted that there are plenty of orchards in Bulgaria, which facilitates access of the suburban martens to fruits (see also Hisano *et al.* 2016). Easy-accessibility to those human-subsidised fruits, along with other potential factors (e.g., availability of artificial dens such as abandoned houses/barns/churches, attic, vehicles; Herr 2010; Hisano *et al.* 2016), could facilitate the martens to adapt to the urban environment in Bulgaria.

Table 2. Fruits and seeds consumed by the Stone Marten in the reviewed papers.

Family	Genus/species	Plant form ^a	Cultivated ^b	Reference ^c
Woody plants				
ROSACEAE	<i>Cerasus sativa</i>	T	*	G13
	<i>Cerasus</i> sp.	T	*	P15, H16
	<i>Malus</i> sp.	T	*	G13, P15
	<i>Prunus cerasifera</i>	T	*	G13, H13, H16
	<i>Prunus domestica</i>	T	*	G13

Family	Genus/species	Plant form ^a	Cultivated ^b	Reference ^c
	<i>Prunus</i> sp.	T		P15
	<i>Crataegus</i> sp.	T		P15
	<i>Pyrus</i> sp.	T	*	G13, G09
	<i>Rosa canina</i>	S		P15, H13
	<i>Rosa</i> sp.	S		G13, G09
	<i>Rubus</i> sp.	T		G13, G09, P15
VITACEAE	<i>Vitis vinifera</i>	L	*	G13
	<i>Vitis</i> sp.	L	*	H16
MORACEAE	<i>Morus</i> sp. (<i>M. nigra</i> or <i>M. alba</i>)	T	*	G13, P15, H16
ERICACEAE	<i>Erica</i> sp.	S		P15
	<i>Vaccinium</i> sp.	S	*	P15
SANTALACEAE	<i>Viscum</i> sp.	P		P15
PINACEAE	<i>Abies</i> sp.	T		P15
CUPRESSACEAE	<i>Juniperus</i> sp.	S		P15
Herbaceous plants				
ROSACEAE	<i>Fragaria vesca</i>	H	*	H16
	<i>Fragaria</i> sp. (wild species)	H		P15
SOLONACEAE	<i>Solanum lycopersicum</i>	H	*	P15
	<i>Capsicum</i> sp.	H	*	P15
CUCURBITACEAE	<i>Cucumis sativus</i>	H	*	P15
POACEAE	<i>Zea mays</i>	H	*	P15
	Poaceae sp.	H		H16
^a T: tall tree, S: shrub, L: liana, P: parasitic plant, H: herbaceous plant. ^b Considered as cultivated plants (human-subsidised foods). ^c G13: Georgiev (2013), G09: Georgiev & Raichev (2009), P15: Petrov <i>et al.</i> (2015), P16: Petrov <i>et al.</i> (2016), H13: Hisano <i>et al.</i> (2013), H16: Hisano <i>et al.</i> (2016). Note that Petrov <i>et al.</i> (2015, 2016) reported fruits consumed by <i>Martes</i> spp.				

It is critical that none of the reviewed studies employed genetic identification for scat origins (e.g., Posluszny *et al.* 2007; Hisano *et al.* 2017). Without this diagnostic approach, faeces of the Stone Marten could not be distinguished from those of the Pine Marten in the regions where they coexist (Petrov *et al.* 2015, 2016). Application of the genetic diagnostic techniques is thus recommended for future studies in Bulgaria. Alternative to this expensive approach, stomach content analysis can also ensure species identification. Using hunted marten samples often restricts study period to autumn-winter (Hisano *et al.* 2013, 2014), but collecting road-killed individuals would enable us to examine the annual marten diet (see Raichev 2014; Iwama *et al.* 2017).

In summary, the Stone Marten in Bulgaria utilised many different fruit species with a large number of cultivated plants, suggesting the marten's opportunistic feeding behaviour in the human-occupied habitat. To help understand adaptability of martens to the urbanised environments, further accumulation of frugivory information is expected by ensuring samples discrimination from those from other sympatric carnivores.

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