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Trophic niche of three carnivores in southern Belgium : raccoon *(Procyon lotor)*, European badger *(Meles meles)* and stone marten *(Martes foina)*

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Abstract

In Belgium, a sighting of raccoons (*Procyon lotor*) was recorded for the very first time in 1986. Howerver, expansion only increased from 2009, particularly in the Ardennes region. It is therefore interesting to study its invasiveness, particularly to study its invasiveness, particularly in terms of trophic competition in relation to indigenous carnivores. This study will compare the diets of raccoons with badgers (*Meles meles*) and stone martens (*Martes foina*). To do this, 142 stomach contents of raccoons and 150 of badgers from the Southern part of Belgium were processed and analysed. For the stone marten, data from a previous study of the diet *via* the faeces, led in the same region, were used. Raccoons mainly consume insects, corn, amphibians, dried fruits and fish, but all classes of vertebrates, invertebrates (oligochaetes, gastropods, arthropods), seeds, dried fruits, fleshy fruits and anthropogenic food remains were found. Badgers do not eat aquatic prey but consume a lot of earthworms, and to a lesser extent slugs, chafer larvae, bumblebee larvae and carrion (dormouse, squirrel...). The trophic overlap of raccoon and badger shows partial overlap, especially of oligochaetes, maize, geotrupes, acorns and carabids (α_{ij} Pianka = 0.53). These items are very abundant in natural environments, especially in open areas. Food competition would therefore be quite low for those two species. The stone marten is quite opportunistic. Its diet mainly includes rodents, birds and hen eggs. Trophic overlap is therefore quite low between and raccoons (0.20) or badgers (0.27).

Running title : Trophic niche of three carnivores

Key words : Trophic overlap, Raccoon, Badger, Stone marten, southern Belgium

INTRODUCTION

Raccoons (*Procyon lotor*) originate from North and Central America. It was introduced voluntarily for its fur into Germany in 1927 near Cassel (Hesse) (LUTZ, 1996) but also into the former USSR from 1936 to 1958 (26 successive releases), and especially into Azerbaijan. But it was from releases made to increase the diversity of game species in Hesse in 1934 that a wild population flourished in Europe. The expansion of this population was relatively slow until the 1960s (DUCHÊNE & ARTOIS, 1988). Gradually, the population spread first to the northeast in the former GDR, then to the north (Schleswig-Holstein), west (Rhineland-Palatinate), southwest (Saarland), south (Baden-Württemberg, Bavaria) and east in the Czech Republic. From 1956 onwards, an eradication attempt was made in Germany but without success (MICHLER *et al*., 2012). Raccoons have continued to expand in all European states except Portugal, Ireland, Finland and the southern Balkan peninsula (BELTRAN-BECK *et al*., 2011).

In Belgium, it was only in 1986 that raccoons were observed for the first time (LIBOIS, 1987). Population growth remained almost nil for 20 years (LIBOIS, 2006), but around 2008, the geographical area in which they were found began to spread further in southern Belgium, especially in the Ardennes. This species is now considered invasive, although the eco-ethological questions raised by this population evolution remain unanswered. Too few studies have been published on the diet of raccoons in Europe, unlike other indigenous carnivores such as badgers (*Meles meles*) and stone martens (*Martes foina*) for which data have been published in the Walloon Region (LAMBINET & LIBOIS, 2010; RICHET *et al*., 2019). The study presented in this article therefore aims to understand the trophic behaviour of raccoons in relation to these other carnivores, especially on bivalves: *Unio crassus* and *Margaritana margaritifera*, both threatened.

In addition, some parasitological analysis were carried out to estimate health risks.

MATERIAL AND METHODS

Raccoon samples (n = 142) were collected from individuals who were victims of road collisions (88) or killed during sanitary shootings (16), traps (9), beatings (8), attacks by hunting dogs (5) or in other circumstances (6), two were also euthanized. For 8 other individuals, the origin of death was not mentioned (Fig. 1). The anamnesis provided for each individual found allows to having age (juvenile/adult) and for most remains, information on the origin of death.

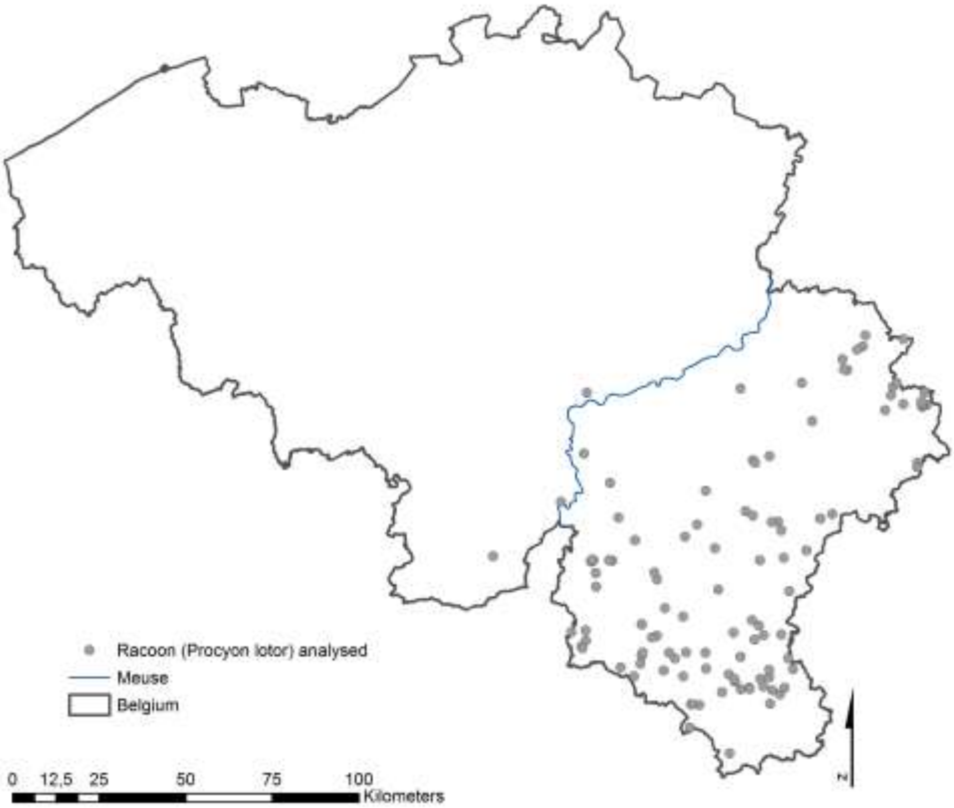


Fig. 1 : Distribution map of raccoon samples

Stomachs were stored in the freezer (-18°C) or in denatured alcohol (70%) before being processed for analysis. The samples are first washed and then directly identified for the soft tissue. The hard parts (chitinous remains, bones, feathers, hair, seeds...) are dried. Remains were identified by analyzing cephalic pieces of fish (LIBOIS *et al*., 1987b), bones or skin of amphibians (BAILON, 1999), scales of small reptiles (ARNOLD & BURTON, 1978), skulls and mammalian hairs (LIBOIS, 1975; DEBROT *et al*., 1982). The characteristic bones of birds were identified directly, as were feathers. However, the determination of species remains very difficult, except in exceptional cases. CHINERY's (1988) work was used for arthropods. The seeds and some fruits from the stomachs were compared with the collection of the Herbarium of the University of Liège.

The stomachs of badgers (n=150) and stone martens (n=26) were treated in the same way (LAMBINET & LIBOIS, 2010; RICHET *et al*., 2019). The stone marten's faeces (n=279) were first soaked in water with a little detergent, dried and then the same procedure as for the raccoon was applied.

It is difficult to quantify dietary intake in carnivores, with the exception of otters (LIBOIS *et al*., 1987a). A semi-quantitative method was chosen. This is the absolute frequency of occurrence (FO) and the relative frequency of occurrence (FO %).

Some individuals have been analysed for the presence of *Baylisascaris procyonis*, a specific nematode that can be quite dangerous for humans (REED *et al*., 2012). A few grams of intestinal contents are first weighed and homogenized with water and then filtered. Then, the samples must be centrifuged (3000 RPM) for 30 seconds. Zinc chloride is added to the pellet so that the nematode's eggs can rise to the surface. Finally, the possible detection of eggs is carried out by observation under the microscope.

The results were processed by different statistical tests: χ^2, reduced deviation, Gtest (SOKAL & ROHLF, 1981) and indices such as diversity (H'), equity (E') (SHANNON, 1948) and overlapping food niches (PIANKA, 1973).

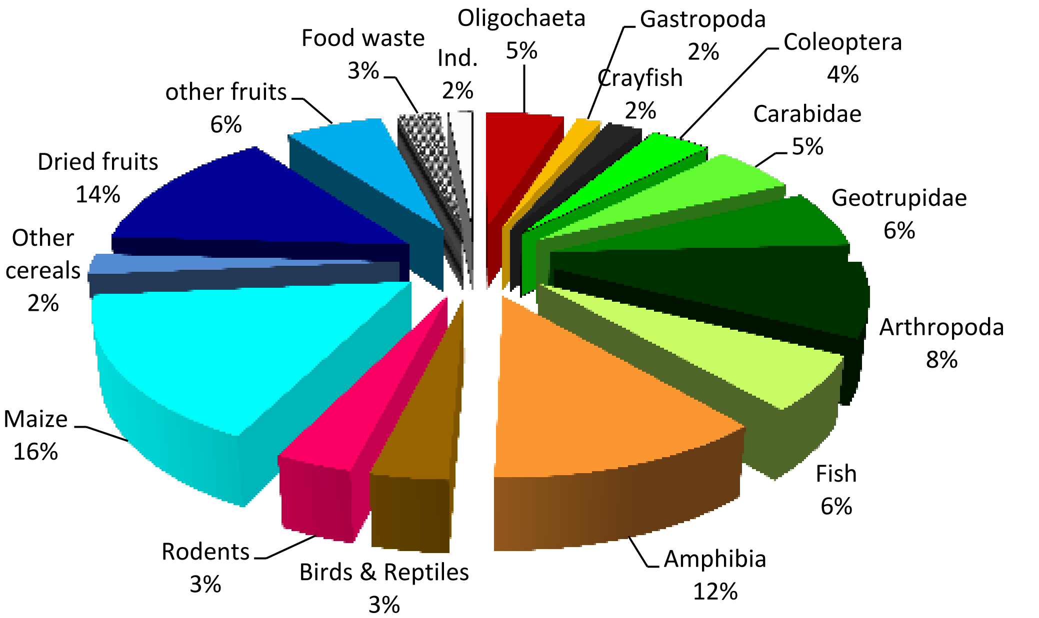
RESULTS

Raccoon

Of the 142 stomachs, 22 were empty (more than 15%). In addition, seven stomachs contained only grass litter and small stones.

The most important items are insects (23%), maize (*Zea mays* - 16%), amphibians (12%) and dried fruits including acorns (*Quercus sp*.), hazelnuts (*Corylus avellana*) and chestnuts (*Castanea sativa*) (14%). Fish, especially sculpins (*Cottus sp*.), take fifth place: 6% (Fig. 2).

Fig. 2: Diet of the raccoon in southern Belgium : relative occurrences the items(nb = 265)



The range of prey is very varied: we find all classes of vertebrates, invertebrates (oligochaete, gastropods, arachnids, crustaceans and insects of several kinds), seeds, dried fruits (achenes), berries (blueberry), drupes (blackberry, cherry) and fleshy fruits (apple). In addition, there were also remnants of anthropogenic food: potatoes peels, spaghetti, paper and a piece of aluminum... (Table 1).

Table 1: Comparison between the feeding of raccoons, badgers and stone marten: absolute frequency of occurrence (FO) and relative frequency of occurrence (FO%) of items.

					Raccoon		Badger		Stone marten	
			nb stomachs & faeces (S. marten)/ items		142/265		150/197		299/493	
					FO	FO %	FO	FO %	FO	FO %
Annelida	Oligochaeta				13	4.91	45	22.84	3	0.61
Mollusca	Gastropoda			Snails	4	1.51				
				Arion sp.			8	4.06		
				Limax maximus			1	0.51		
Arthropoda										
	Crustacea	Astacoidea		crayfish	5	1.89				
		Oniscidea	Isopoda	woodlouse	1	0.38				
	Myriapoda	Chilopoda							3	0.61
	Arachnida				1	0.38				
	Insecta				1	0.38	3	1.52	27	5.48
		Coleoptera			10	3.77	8	4.06	5	1.01
			Carabidae		14	5.28	9	4.57	11	2.23
			Dytiscidae		1	0.38				
			Geotrupidae		17	6.42	19	9.64	15	3.04
			Silphidae	*Necrophorus sp.*			1	0.51		
			Scarabaeidae						7	1.42
				Cockchafer (larvae)			9	4.57		
			Coccinellidae		1	0.38				
			Curculionidae		1	0.38				
		Lepidoptera		(caterpillars)	3	1.13	5	2.54	17	3.44
		Trichoptera		caddisflies	2	0.75				
		Hymenoptera			1	0.38	1	0.51		
			Vespidae	wasp	1	0.38	1	0.51	2	0.41
			Apidae	*Bombus sp.* (larvae)			3	1.52		
			Formicidae	ant			2	1.02	3	0.61
		Diptera			2	0.75				
			Tipulidae	tipula			3	1.52		
			Syrphidae	(larvae)					3	0.61
		Hemiptera			1	0.38				
		Orthoptera			1	0.38				
		Odonata			4	1.51				
		Dermaptera	Forficulidae	earwig	2	0.75				

Fishes		Cottidae		*Cottus sp.*	14	5.28				
		Gasterosteidae		*Gasterosteus gymnurus*	1	0.38				
		Salmonidae		*Salmo trutta*	1	0.38				
Amphibia										
	Anoura				20	7.55	2	1.02		
		Ranidae		*Rana sp.*	4	1.51				
		Bufonidae		*Bufo sp.*	3	1.13	1	0.51		
				Eggs	4	1.51				
	Urodela				1	0.38				
Reptiles	Squamata	Lacertidae		*Zootoca vivipara*	1	0.38				
		Anguidae		*Anguis fragilis*	1	0.38				
Birds			(bones, feathers)		3	1.13			72	14.60
	Galliformes	Phasianidae		*Gallus*			1	0.51		
				Gallus (Eggs)			1	0.51	34	6.90
		Turdidae		*Turdus sp.*	1	0.38				
				Turdus merula	1	0.38				
Mammals							3	1.52		
	Insectivora	Soricidae							2	0.41
	Carnivora	Mustelidae		*Mustela sp.*					1	0.20
	Lagomorpha								1	0.20
	Rodentia	Microtidae			6	2.26	9	4.57	102	20.69
		Muridae		*Apodemus sp.*	3	1.13	1	0.51	17	3.45
				Mus domesticus					4	0.81
		Sciuridae		*Sciurus vulgaris*			1	0.51		
		Gliridae		*Eliomys quercinus*			2	1.02		
Plants	Poaceae			*Zea mays*	43	16.23	8	4.06		
				Triticum sp.	2	0.75	1	0.51	5	1.01
				"cereals"	3	1.13			6	1.22
	Fabaceae			*Pisum sativum*	1	0.38			12	2.43
Dried fruits					3	1.13				
	Fagaceae		acorn	*Quercus sp.*	21	7.92	8	4.06		
			chestnut	*Castanea sativa*	3	1.13				
	Betulaceae		hazelnut	*Corylus avellana*	10	3.77	5	2.54		
			achene	*Carpinus betulus*			1	0.51		
	Aceraceae		samara	*Acer sp.*			1	0.51		
Fruits										
	Taxaceae		aril	*Taxus baccata*					6	1.22
	Ericaceae		blueberry	*Vaccinium sp.*	1	0.38				
	Grossulariaceae		black-redcurrant	*Ribes sp.*					5	1.01
	Rosaceae		black-raspberry	*Rubus sp.*	5	1.89	8	4.06	7	1.42
			strawberry	*Fragaria sp.*			1	0.51		
	Amygdalaceae		plum, mirabelle	*Prunus sp.*	1	0.38	5	2.54	17	3.45
			wild cherry	*Prunus avium*	2	0.75	1	0.51	1	0.20
			cherry	*Prunus cerasus*	1	0.38	2	1.02	8	1.62
	Malaceae		apple	*Malus sp.*	3	1.13	3	1.52	1	0.20
	Cornaceae			*Cornus mas*			2	1.02		

	Vitaceae	grapes	*Vitis vinifera*					3	0.61
	Rutaceae	citrus fruit	*Citrus sp.*					1	0.20
	Solanaceae	tomato	*Lycopersicon esculentum*					3	0.61
	Caprifoliaceae		*Sambucus nigra*			1	0.51	5	1.01
	?	berry		3	1.13			10	2.03
Seeds						7	3.55	4	0.81
	Asteraceae	sunflower	*Helianthus annuus*			1	0.51	7	1.42
	Linaceae	linen	*Linum sp.*					28	5.68
Food waste				7	2.64	3	1.52	31	6.29
Carrion									
	Falconiforme			1	0.38				
	Colombiforme		*Columba palumbus*	1	0.38				
	Artiodactyla		*Sus scrofa*					4	0.81
Ind.				4	1.51				
H'				4.83		4.44		4.04	
E'				0.84		0.83		0.76	

More than fifty food categories have been identified. The diversity of Shannon H' (4.820) is very high. The equity index is also important (E' = 0.838). These various indicators lead to the conclusion that the raccoon is a great opportunist, and can sometimes even behave like a scavenger (raptor, wood pigeon).

The diet does not differ according to the sex of the individuals (Table 2) (Gtest $_{ddl\ 15}$: 8.33 n.s.). Diversity and equity are roughly equivalent: H' = 4.595, E' = 0.869 (females); H' = 4.634, E' = 0.859 (males). In addition, there is no difference between the two sexes in the probability of being involved in a collision (χ^2 = 1.14; n.s.). However, during dissections, more males (nb = 94) than females (nb = 42; Reduced gap: 4.46; $p < 0.0001$) are collected.

Table 2: Comparison between the feeding of raccoons as a function of sex, FO and FO%

	M		F		Gtest	
nb stomachs / items	74/159		34/84		ddl = 15	
	FO	FO%	FO	FO%	8,33	ns
Oligochaeta	8	5.03	4	4.76	ns	
Gastropoda	3	1.89	1	1.19	ns	
Crayfish	2	1.26	3	3.57	ns	
Coleoptera	6	3.77	2	2.38	ns	
Carabidae	6	3.77	7	8.33	ns	
Geotrupidae	12	7.55	5	5.95	ns	
Arthropoda	13	8.18	7	8.33	ns	
Fish	8	5.03	8	9.52	ns	
Amphibia	18	11.32	13	15.48	ns	
Birds & Reptiles	6	3.77	2	2.38	ns	
Rodents	5	3.14	2	2.38	ns	
Cereals	34	21.38	12	14.29	ns	
Dried fruits	21	13.21	10	11.90	ns	
other fruits	10	6.29	5	5.95	ns	
Food waste	4	2.52	2	2.38	ns	
Ind.	3	1.89	1	1.19	ns	
H'	4.634		4.595			
E'	0.859		0.869			

Table 3 compares the diet of juveniles with that of individuals in other age categories: no significant differences are found compared to adults and sub-adults (Gtest $_{ddl\ 15}$: 14.86 n.s.) except for fish (Gtest partiel = 5.27 $p < 0.05$) and beetles (Gtest partiel = 4.92 $p < 0.05$). It may therefore be that juveniles do not yet possess fishing techniques. Dietary diversity is slightly lower among juveniles but remains high (H' = 4.135 *vs* H' = 4.782). Equitability is also very comparable: 0.870 *vs* 0.866.

Table 3: Comparison between the feeding of raccoons as a function of age, FO and FO%

	Raccoon					
	Juveniles		Adults		Gtest	
nb stomachs / items	44/77		96/174		ddl = 15	
	FO	FO%	FO	FO%	14.86	ns
Oligochaeta	4	5,19	9	5.17		
Gastropoda	1	1.30	3	1.72		
Crayfish	1	1.30	3	1.72		
Coleoptera	6	7.79	3	1.72	4.92	p < 0.05
Carabidae	5	6.49	9	5.17		
Geotrupidae	7	9.09	10	5.75		
Arthropoda	5	6.49	16	9.20		
Fish	1	1.30	14	8.05	5.27	p < 0.05
Amphibia	9	11.69	23	13.22		
Birds & Reptiles	1	1.30	7	4.02		
Rodents	2	2.60	5	2.87		
Cereals	15	19.48	32	18.39		
Dried fruits	13	16.88	21	12.07		
other fruits	5	6.49	10	5.75		
Food waste	1	1.30	6	3.45		
Ind.	1	1.30	3	1.72		
H'	4.135		4.782			
E'	0.870		0.866			

Finally, the diet comparison was divided into three quadrants: winter months (November to February), spring (March to June) and summer-fall (July to October). The Gtest $_{ddl\ 30}$ is significant: 45.95 $p < 0.05$) (Table 4). In winter, amphibians dominate (partial Gtest = 10.16 $p < 0.01$). In spring, amphibians and rodents (partial Gtest = 7.13 $p < 0.05$) are predominant in the diet. In summer and autumn, fleshy berries and fruits are consumed (partial Gtest = 6.27 $p < 0.05$). The diversity of food items consumed is quite low in winter (H' = 3.767), average in spring (H' = 4.375) and higher in summer-fall (H' = 4.712). The number of different categories also varies according to the season: in winter, there are fewer items (17), in spring, their diversity increases (27), and in summer/fall, this trend increases further (42). However, equitability is less important (E' = 0.874): the food resources are varied and allowed the raccoon to choose his menu more easily. Raccoons are more eclectic in winter (E' = 0.922) and in spring (E' = 0.920) when food is less abundant.

Table 4: Comparison between the feeding of raccoons according to the seasons, FO and FO%

	Raccoon							
	N-D-J-F		M-A-M-J		Jl-A-S-O		Gtest	
nb stomachs / items	24/46		47/58		62/136		ddl = 30	
	FO	FO%	FO	FO%	FO	FO%	45.95	< 0.05
Oligochaeta	3	6.52	2	3.45	6	4.41	ns	
Gastropoda	1	2.17	1	1.72	1	0.74	ns	
Crayfish			3	5.17	2	1.47	ns	
Coleoptera	2	4.35			6	4.41	ns	
Carabidae	3	6.52	2	3.45	7	5.15	ns	
Geotrupidae	1	2.17	4	6.90	10	7.35	ns	
Arthropoda	2	4.35	5	8.62	15	11.03	ns	
Fish	3	6.52	3	5.17	10	7.35	10.16	<0.01
Amphibia	12	26.09	9	15.52	9	6.62	ns	
Birds & Reptiles	1	2.17	3	5.17	5	3.68	7.13	<0.05
Rodents			5	8.62	3	2.21	ns	
Cereals	10	21.74	14	24.14	22	16.18	ns	
Dried fruits	6	13.04	3	5.17	21	15.44	6.27	<0.05
other fruits	1	2.17	1	1.72	13	9.56	ns	
Food waste	1	2.17	2	3.45	3	2.21	ns	
Ind.					3	2.21	ns	
H'	3.767		4.375		4.712			
E'	0.922		0.920		0.874			

Trophic overlap of the three carnivores

Of the three species studied, the raccoon's diet appears to be the most varied: 55 different items compared to 41 and 39 for badgers and stone marten respectively (Table 1). The Shannon indices (H') are in the same direction: 4.83, 4.44 and 4.04 respectively. Equitability is almost equal for raccoons and badgers (0.84 vs 0.83) but decreases for stone marten (0.76) which are less generalist.

The trophic overlap index for raccoons and badgers (α_{ij} Pianka = 0.53) shows partial overlap, especially for oligochaete, maize, geotrupes, acorns and carabids and to a lesser extent for ind. beetles, anurans, hazelnuts and voles. It must be said that these items are very abundant in the natural and agricultural environments. The differences are rather inherent in the eco-ethology of these species: the raccoon consumes aquatic prey (fish, crayfish, dytiscids, trichoptera, odonates), which is not the case for badgers. On the other hand, badgers are more likely to frequent intermediate areas between open (grasslands, crops) and closed areas (forests and their edges) and consume slugs, chafer larvae, bumblebee broods and even, sometimes, arboricultural mammals, squirrels (*Sciurus vulgaris*), garden dormice (*Eliomys quercinus*) perhaps carrion.

The trophic overlap index between raccoon and stone marten is significantly lower (α_{ij} Pianka = 0.20). Between the stone marten and the badger, the overlap is of the same order (α_{ij} Pianka = 0.27). The marten mainly consumes microtids, birds and hen eggs, fleshy and beer fruits (cherries, plums, tomatoes, grapes, currants, black elder...) and seeds (*Linum sp*.). On the other hand, oligochaetes are rare in its menu. Amphibians, fish, dried fruit and maize are absent from the diets of both mustelids.

In raccoon samples, inert remains were found such as soil, small stones, leaves, spruce needles, wood, mosses and in a quarter of stomachs, grasses. These elements seem, most of the time, to be consumed accidentally at the same time as prey. For badgers, it's a little different: they ingest grass (48% of stomachs) depending on the season, more so in winter and much less in summer. Inert remains are quite rare: less than 7% (RICHET *et al*., in prep.). In the faeces of the very anthrotrophic stone marten, we find paper, wood, plastic, polystyrene, rubber, nylon, cotton wool, string, tissue, aluminium, elastics, synthetic fibres and even glass fibre (LAMBINET & LIBOIS, 2010) !

Sixteen raccoons from different regions (Fagne-Famenne, Lorraine, Hautes-Fagnes, Ardenne) were analysed for the parasite *Baylisascraris procyonis*: they all tested negative.

DISCUSSION

In Wallonia, the raccoon's diet is very varied, as the results of this study show. There is a very strong attraction of raccoon to cultivated plants, especially corn, whether in pasty form in the fields or dry in silos. Damage to maize crops is well known in North America (BEASLEY & RHODES, 2008; MACGOWAN *et al*., 2006). In the Ardennes, the way corn cobs are consumed, depending on the species, does not easily make it possible to distinguish between those eaten by raccoons and badgers. However, in either case, damage is generally small in the affected plots. Finally, in our region, the raccoon also confirms its status as a major food opportunist, already established in Europe (BARTOSZEWICZ *et al*., 2008; HOHMANN & BARTUSSEK, 2011; ENGELMANN *et al*., 2011; RUYS, 2014). In the coastal and humid tropical forests of its original range, it eats mainly crabs and fruits (CARRILLO *et al*., 2001). On Florida beaches, it also consumes sea turtle eggs (*Caretta caretta*) (BRANDON *et al*., 2007). In low-lying rivers, crayfish and fruits (berries and acorns) are the most frequently consumed items, while in low-lying mountains (Minnesota). Berries and fruits are preferred in July and maize and acorns in September (SCHOONOVER & MARSHAL, 1951). AZEVEDO *et al.* (2006) find only cereals (corn and wheat), bird remains and egg shells (Canada, southern Saskatchewan).

In Europe, data on the diet of raccoons are relatively sparse and have been mainly studied in Germany. In 1980, LUTZ (1980) analysed the stomachs in northern Hesse indicating that mammals and birds were regularly on the menu of raccoon, whereas they are rarely consumed in the Ardennes. The frequency of other items (insects, other invertebrates and plants) is more comparable to that found in Wallonia, but we also find more amphibians (12.1% *vs* 0%) and fish (6% *vs* 2%) than in Hesse. More recently, an in-depth study of the raccoon diet was conducted in the Müritz National Park (Mecklenburg-Western Pomerania) by ENGELMANN *et al.* (2011). The results cover more than 200 faeces samples and show the presence of earthworms in 41.8% of faeces (associated biomass: ± 30%; frequency < 5% in the Walloon Region), insects in 93% of the samples (relative biomass of 6%) compared to 37% in Belgium; molluscs are much more frequent (57.9% ; 6.6% of the biomass) on the menu than in the Walloon Region (<3%), while fruits are encountered almost as often (31.4% *vs* 27% in the Ardennes ; biomass of ± 25%). Nuts are also well represented (24.3% of samples). Amphibians are identified more often than in our country, in 22.4% of stomachs (*vs*. 12.1% in Wallonia), and account for 4.8% of the biomass. Maize is common in the raccoon diet: 20% of German samples and 30% of ours; mammals are found in 15.1% of the stomachs of the Müritz NPP (biomass: 3.5%), fish in less than 7% (biomass: 3.4%) which is in line with our own values (6%). On the other hand, in Germany, birds were found in 12.7% of the samples (biomass: 1.8%) compared to 3.5% in our country.

MICHLER (2006) considers the raccoon to be an occasional predator of chicks or eggs but rarely of adult birds. KOWARIK (2003) and WINTER (2005) have not provided evidence that raccoon predation on ground-nesting birds has an effect on their populations. On the other hand, in the wetland of the National Park at the mouth of the Warta River in Poland, 15% of the biomass ingested by Polish raccoons is composed of birds (BARTOSZEWICZ *et al.*, 2008): this appears high but it must be considered that waterbirds abound in this region, to such an extent that it is even surprising that this food category is not even more important on the raccoon's menu. Mammals are also eaten in significant quantities, unlike fish and plants. Among mammals, many deer (*Cervus elaphus*) and wild boar (*Sus scrofa*) hairs were identified in the faeces analysed by Polish colleagues, confirming the scavenging nature of the raccoon. Finally, in Spain, on the other hand, raccoon predation on birds is higher than in other European regions where the diet of raccoon has been studied.

Given the astonishing diversity of its menu both in its natural range and in Europe, *Procyon lotor* appears to be more of an opportunistic hypergeneralist species and is considered a collector or gatherer by some authors (LLEWELLYN & WEBSTER, 1960; GREENWOOD, 1981; KAUFMANN, 1982; SANDERSON, 1987; ZEVELOFF, 2002; CENTRE D'EXPERTISE EN ANALYSE ENVIRONNEMENTALE DU QUÉBEC 2006, MICHLER, 2007; BARTOSZEWICZ *et al.*, 2008; HOHMANN & BARTUSSEK, 2011; ENGELMANN *et al.*, 2011; RUYS, 2014) than as a predator in the strict sense. In most cases, it favours the most abundant, or even easiest to access, food items.

In all regions of the world where it occurs, raccoons have colonized urbanized habitats, even in cities, and have learned to exploit anthropogenic food waste to such an extent that populations are denser than in rural areas (ZEVELOFF, 2002; SCHWAN, 2003; IKEDA *et al.*, 2004; HOHMANN & BARTUSSEK, 2011; RUYS, 2014; BATEMAN & FLEMING, 2012).

In some circumstances, badgers may be specialists in oligochaetes (KRUUK & PARISH, 1981; MOUCHÈS, 1981; VIRGOS *et al.*, 2004) but they are quite plastic: they adapt to local resources (HENRY, 1984; FERRARI, 1998; FENG *et al.*, 2013). In addition, MARTIN *et al.* (1995) and FISCHER *et al*. (2005) report specialization for certain prey at the population level and also at the individual variation level. In Wallonia, the badger seems to adopt a generalist-opportunistic behaviour with a preference for earthworms when they are available. The trophic overlap with raccoons is quite high, but it occurs for abundant resources: corn, earthworms, geotrupes, carabids, acorns, small rodents. In this context, interspecific competition is therefore low.

In temperate Europe, the stone marten mainly consumes voles, passerines and hen eggs. However, she likes stone fruits (cherry, wild cherry plum, Mirabelle, sloe), pome fruits (apple and pear), berries and drupes (blackberry and raspberry, currant, rosehip...). They also eat earthworms, beetles, caterpillars and household waste. However, it neglects dried fruits and corn (WAECHTER, 1975; KALPERS, 1983; LIBOIS, 1991; LANSZKI, 2003; LAMBINET & LIBOIS, 2010). It is much more humane than other carnivores but less generalist than badgers or raccoons.

The prevalence of the nematode (*Baylisascaris*) is very high in Germany: 39% overall but it can increase to 74% in some regions, such as Hesse (HOHMANN *et al*., 2002, GUNESCH, 2003, WINTER, 2005, BELTRAN-BECK *et al.,* 2011). This prevalence is much lower in the Warta mouth National Park (Poland) near the German border: 3.3% (POPIOLEK *et al*., 2011). In Wallonia, the samples studied in 2012 were all negative. Since then, regular analyses conducted by our veterinary colleagues (com. pers. Y. Caron) have confirmed zero prevalence. One explanation could be a depletion of parasitic fauna in colonizing individuals (LIBOIS *et al.,* 1997; TORCHIN *et al*., 2003), but it could also be that prevalence is linked to the migration routes of individuals from different genetic subpopulations from the east, who would themselves have highly variable prevalences of the nematode. In this context, raccoons that have colonized our region could be relatively healthy. However, it is necessary to investigate this question in the long term, particularly because East Belgium seems to be mainly colonised by individuals from German regions where the prevalence of *B. procyonis* is high (pers. com. A. Frantz). Finally, it should be noted that the danger that this disease represents for humans remains to be put into perspective: in 2011, BAUER *et al.* (2011) reported 3 cases of contamination in humans in Germany after more than 70 years of cohabitation with this exotic species and these people were all in close contact with raccoons.

CONCLUSIONS

In southern Belgium, raccoons adopt a generalist feeding behaviour of the hyper-opportunistic type, more so than badgers and stone martens. The food categories selected by the raccoon (55) are more varied than those found in the south of these two mustelids (41 and 39 respectively). In fact, raccoons also eat aquatic prey: fish, odonates, trichoptera, crayfish and amphibians, which badgers and stone martens do little to prevent. To date, bivalves have not been found in any raccoon stomach samples. Corn is an important component of the diet, more important than badgers. The trophic overlap index is quite high compared to badgers, but it concerns abundant items in rural areas. Badgers are also opportunists, they are not very active predators: they consume items at ground level or in the ground, mainly oligochaete, geotrupes, carabids, chafer and bumblebee larvae, dried and fleshy fruits...

On the other hand, the stone marten actively looks for small rodents and passerines (Turdidae large and small, starling, Sylviidae, small Corvidae...), pigeons, hens and eggs. Fleshy fruits and berries are best enjoyed in late summer and early autumn. Compared to badgers and raccoons, stone martens are the least generalist.

The data presented here therefore do not give cause for concern about raccoon predation and possible interspecific competition with stone marten and badger. In winter, however, food resources are more limited, one might think that there would be active competition between these carnivores, but the samples analysed at that time of year for three species are not sufficient to conclude on this issue.

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