

University of Lisboa  
Faculty of Sciences  
Animal Biology Department



# The effect of habitat fragmentation in the diet of pine marten

Duarte Henrique Marques Mestre  
Mestrado em Biologia da Conservação

2012

University of Lisboa  
Faculty of Sciences  
Animal Biology Department



# The effect of habitat fragmentation in the diet of pine marten

Duarte Henrique Marques Mestre

Mestrado em Biologia da Conservação

Dissertation oriented by Prof. Dra. Marie Lazarine-Poulle  
(Director of 2C2A-CERFE) and by Prof. Dra. Margarida Santos-Reis  
(DBA/CBA - FCUL)

2012

## Acknowledgements

“Adapt or perish, now as ever, is nature's inexorable imperative.  
H. G. Wells”

First of all I just would like to say that this whole experience was wonderful and I am indebted to all that contributed to it. I really hope that this work will have a role in conservation of this species. This study opened my eyes to the many problems biologists have on the field regarding the acceptance of people who don't understand why there are a bunch of (crazy) people collecting scats of the ground of a species that they hunt and don't really care about. To all of the people that allowed me to go on the field for hours and hours of collecting scats a most sincere thank you.

I, of course, would like to thanks my parents for providing me the opportunity for going on Erasmus by car because without them I would not be able to enjoy this once-in-a-lifetime chance. To my Professor Francisco Petrucci-Fonseca I also thank for his invaluable help choosing the university which I ended up going to and for the long hours of laughs about our common passion, football. Particular thanks are due to my supervisors Marie Lazarine-Pouille, Marina Mergey and Margarida Santos-Reis. To Marie Lazarine for always being there for me and for her priceless help in my stay in France. You were indeed the supervisor that everybody would like to have and I will always be thankful. Big thanks also for Marina for putting up with my incessant questions, for going with me to the field collecting the scats and for all the time laughing and sharing for the duration of time there. To professor Santos-Reis a most sincere thank you for all the knowledge regarding mammals you have given me. Without it I could never have done this dissertation. Your advices regarding the contents of this work improved by far the quality of this document. Thank you all for putting your confidence in me, providing support and making this a most enjoyable experience.

Thanks are also in order for Professor Henrique Cabral for helping with a statistical problem I had and by showing that I could count on him for help and to

professor Rui Rebelo for helping throughout the whole process of writing this document.

To all the people in the CERFE and in France I thank you with all my heart. You all were the most amazing people someone could ever wish for. You made me feel like I was home and I consider Boult-aux-Bois my second home because of you. To Rémi Helder a most sincere thank you for the classification of woodland you did. It was a most valuable contribution to my dissertation. Thomas, Clara, Carole Bodin, Carole Brendel, Marina and Marie Amélie I appreciate all you have done for me I wish you all a happy life. To everybody else that made me laugh you all know you are very important to me.

I could not have done this without the love and support of my family: my parents Cila and José, my cousin Ana, my aunt Maria Helena, uncle Octávio and my grandparents João and Conceição and my “cousin” Pedro.

Last but not least, to my all my friends from Portugal for reminding me every day that I was working with animal droppings (making fun of me) and for your support in me going on Erasmus. A very special thanks to José Ricardo, my “brother”, Francisco Moreira, Gonçalo Rodrigues, Sónia Tomás, João Fernandes, Maria Estudante, João Sobrinho, Cátia Vanessa, Tomé Matos and everyone else for being there for me. May we never forget each other and remain good friends for our whole lives.

## Abstract

The european pine marten *Martes martes* (Linnaeus 1758) is a member of the Mustelidae family, comprising such members as weasels, stoats, polecats, mink, marten, fishers, wolverines, otters, badgers and others. This family of carnivores has a high influence in the food chain of many habitats and its protection depends on finding a compromise on the degree of human actions in the environment.

With the increase of forest fragmentation all around the globe in the last century, it becomes essential to understand the role played by habitat fragmentation in forest-type habitats. This project regards the possible differences between the diet of European marten (*Martes martes*) in a fragmented and a non-fragmented area in the northeast of France, specifically in the Ardennes region. This work's objectives are: (i) to understand the results obtained within the general theme of forest management and conservation of pine marten; (ii) to compare pine marten diet in a fragmented and a non-fragmented area, regarding one of the pine marten's basic resource (rodents); (iii) To speculate about resource availability, regarding the results.

To accomplish the objectives of we performed transects in two different kinds of habitat to retrieve pine marten droppings. After a genetic analysis of the droppings, the eating habits of the species were studied through the verification of the content of the droppings and related to the variation of types of prey on both sites.

The results we obtained allow us to conclude that the pine marten explores other trophic resources in fragmented areas such as the consumption of seeds and that it goes outside of its preferred habitat to feed therefore adapting to an high degree of habitat fragmentation.

Keywords: pine marten; habitat fragmentation; diet; conservation

## Resumo

Salvar a biodiversidade teve, nas últimas décadas, uma atenção especial nos níveis mais baixos da biodiversidade. Menos atenção tem sido dada à identificação dos processos ambientais que ameaçam a biodiversidade, e como estes são susceptíveis de se alterarem num futuro próximo (Debinski e Holt, 2000).

A perda e fragmentação de habitat, em termos de conservação da biodiversidade, está entre as principais preocupações ambientais actualmente, mas os mecanismos subjacentes a fenómeno são difíceis de identificar e compreender, tal como os respectivos impactos. Esta importância relativamente a estes fenómenos prende-se pelo efeito negativo proveniente dos mesmos. Existem vários exemplos desses efeitos como um aumento no índice da mortalidade de indivíduos que se deslocam entre zonas de habitat e uma redução do tamanho de populações locais originando uma maior vulnerabilidade à extinção (Fahrig e Merriam, 1994).

O conhecimento profundo dos factores prejudiciais para a biodiversidade deve ser o componente mais importante do planeamento de conservação e, como tal, a falta desse mesmo conhecimento, especialmente no que toca à relação entre os efeitos da fragmentação de habitats sobre as populações de mamíferos no topo da cadeia alimentar, provoca um entrave à conservação das espécies.

A espécie estudada, a marta (*Martes martes*) é um carnívoro de médio porte cuja dieta é predominantemente carnívora (Jedrzejewski et al 1993, Baltrûnaitė 2002, Caryl 2008). Na região escandinava, a marta é frequentemente categorizada como uma espécie especialista, porque está dependente de manchas de floresta antiga com possíveis locais de descanso e de nidificação, a fim de estar protegida contra predadores.

Esta espécie está distribuída por toda a França e está, supostamente, regredindo ao longo dos séculos como resultado de envenenamento por armadilhas e fragmentação florestal (Maurin, 1992).

Alguns tópicos de ecologia da marta como dieta (Nyholm 1970, Garzon et al. 1980, Reig e Jedrzejewski 1988, Jedrzejewski et al. 1993, Clevenger 1993, Pulliainen & Ollinmaki 1996, Helldin 2000), área vital (Zalewski et. al. 1995, Caryl 2008) e preferências de habitat (Brainerd e Rolstad 2002) foram dissecados ao longo dos anos, mas a nossa percepção dos elementos que limitam a densidade e distribuição da marta europeia permanecem em grande parte inexplicados (Helldin 1998).

O papel ecológico preenchido pela espécie é muito importante e é bastante diversificado. É principalmente um predador, mas é também um necrófago e complementa sua dieta com material vegetal, portanto, pode ser classificada como omnívora (Marchesi e Mermoud 1989).

A marta foi escolhida como modelo de estudo devido ao impacto que a espécie tem nos vários degraus da cadeia trófica e também devido à sua matriz de necessidades ecológicas. Outras influências que levaram a esta escolha foram as de que esta era uma espécie pertencente a um projecto de conservação decorrendo na região e que este estudo nos pode mostrar como a população local de marta subsiste contra uma alta percentagem de fragmentação do seu habitat.

Satisfazer as necessidades alimentares de cada espécie é uma das questões fundamentais da ecologia. Isso ocorre porque o alimento é o principal agente regulador das populações e, portanto, ao estudar a disponibilidade de recursos alimentares e como as espécies as aproveitam, podemos usar essas informações para ajudar a preservar a espécie.

Neste trabalho, os nossos objectivos foram os de identificar possíveis diferenças na alimentação da marta variando de uma zona de floresta contínua para uma com elevado grau de fragmentação e de integrar os resultados obtidos no espectro de informações sobre a ecologia e conservação da marta.

Os nossos dois locais de estudo, uma área de floresta fragmentada e outra de floresta contínua, foram assim divididos em forma de grelha e em cada quadrado foi realizado um transecto de 2 km através de zonas de floresta, para a recolha de dejectos.

As zonas de floresta foram definidas através do programa ArcView 3.2 por um especialista com conhecimento do terreno.

Os dejectos recolhidos foram então enviados para o laboratório na Universidade de Lyon para identificação das espécies utilizando marcadores moleculares.

Os dejectos que foram identificados positivamente como marta foram depois analisados em laboratório de forma a conhecer a dieta da espécie. Os elementos que encontrámos foram categorizados em cinco classes de acordo com os vestígios encontrados: "Roedores", "Aves", "Sementes", "Insectos" e "Outros mamíferos". A classe "Outros mamíferos" incluiu carcaças e animais insectívoros. Os resultados foram expressos em termos de ocorrência relativa dividindo-se o número de dejectos em que a presa ocorreu com o número total de dejectos analisados.

As diferentes classes de alimento foram classificadas quanto à sua importância no espectro de alimentos.

A classe "Sementes" apenas estava presente no local de estudo com floresta contínua com uma classificação de "uso constante", devido à sua percentagem de ocorrência (11%) e foi a diferença mais notável entre os dois locais de amostragem. Foram identificadas duas espécies nesta categoria: *Rosa canina* L. e *Prunus avium*, duas espécies não florestais.

A classe "Roedores" foi a mais representada tendo uma percentagem de ocorrência total de perto de 50% em ambas as áreas enquanto a classe "Aves" também ela estava bem representada na dieta com valores a rondar os 30%. Ambas as classes são consideradas recursos básicos na dieta da marta.

As restantes classes, "Insectos" e "Outros mamíferos", representaram cerca de 11 e 2 % respectivamente, tendo esta última apenas elementos encontrados no local de estudo com floresta contínua.

Com os dados obtidos testámos a hipótese nula das dietas não serem diferentes e, não tendo rejeitado essa hipótese, fomos verificar se o mesmo acontecia relativamente à classe "Roedores" tendo obtido o mesmo resultado de não-rejeição da hipótese em teste. Face a estes resultados fomos então verificar se a proporção de "Roedores" é



homogénea, ou seja, se cada recurso desta classe é explorado de igual forma onde o resultado foi altamente significativo.

Para complementar os resultados anteriores decidimos avaliar a amplitude da exploração de recursos calculando o índice de Shannon-Wiener (Krebs 1999) de amplitude de nicho trófico ( $H'$ ) e recorrer a uma comparação estatística da amplitude ambos os nichos. O teste t resultante não rejeitou a hipótese nula de nichos não diferentes.

Finalmente usamos o índice de Pianka (Pianka 1973 em Krebs 1999) para ver como ambos os nichos se sobrepõem. O resultado obtido foi uma sobreposição quase total (0,97) dos mesmos.

Finalmente, a fim de adquirir uma melhor compreensão sobre os hábitos alimentares da marta, foram usados os dados adquiridos relativamente ao local de floresta fragmentada. Nessa análise separaram-se os elementos da classe “Roedores” em 2 grupos usando as suas preferências de habitat como critério de escolha.

Comparou-se então os dois grupos usando a percentagem de habitat correspondente a cada grupo para o cálculo no número de elementos que se esperaria ter encontrado se o uso de habitat fosse igual. O teste revelou que a marta mostra preferência por zonas de floresta mas que explora habitats não florestais em busca de presas.

Como tal as principais conclusões deste estudo são de que a marta é um animal que se adapta bem a ambientes altamente fragmentados, saindo do seu habitat preferencial para explorar os recursos tróficos existentes noutros habitats.

Outra conclusão que os dados nos permitem retirar é de que os elementos da classe “Sementes” são usados como complemento da dieta da marta em habitats fragmentados levando a uma especulação de que os recursos básicos da sua dieta não são suficientes para as suas necessidades ecológicas.

As limitações deste trabalho prenderam-se pela proporção de dejectos encontrada em ambos os locais (5 para 1 a favor do local com fragmentação florestal) levando a uma comparação dieta muito menos robusta do que a que poderia ter sido feita. Outra limitação foi o facto de não termos procedido à identificação de espécies de

aves como foi feito noutros trabalhos que poderia dar-nos indicações relativamente a possíveis efeitos da fragmentação de habitat neste recurso essencial na dieta da marta. Finalmente o número de dejectos analisados poderia ter sido maior para prevenir a possível ausência de certas presas do espectro alimentar analisado e para melhorar a nossa análise em relação à sua robustez.

Uma medida necessária para aumentar o nosso conhecimento sobre o tema é o de se realizar um estudo sobre o uso da paisagem por martas em um habitat altamente fragmentado, a fim de maximizar os esforços de conservação. Seria também importante caracterizar um espectro elevado de fragmentos florestais (diferentes tamanhos, formas, espécies vegetais) no que toca aos dois factores mais importantes na ecologia da marta: a existência de locais de descanso e nidificação e a disponibilidade de presas. O conjunto de informações obtido nestes estudos seria essencial para a conservação da espécie.

Palavras-chave: marta; fragmentação de habitat; dieta; conservação.

## Index

<b>1. Introduction.....</b>	<b>1</b>
<b>2. Materials and methods.....</b>	<b>8</b>
2.1 Study site.....	8
2.2 Field sampling.....	9
2.3 Diet analysis.....	10
2.4 Diet comparison.....	11
2.5 Resource exploration.....	12
<b>3. Results.....</b>	<b>14</b>
3.1 Diet analysis.....	14
3.2 Diets comparison.....	16
3.3 Resource exploration.....	19

<b>4. Discussion.....</b>	<b>20</b>
<b>5. Bibliography.....</b>	<b>26</b>

## Introduction

### The current landscape scenario

The existing setting regarding landscape and especially forest landscape in Europe is mostly the result of thousands of years of occupation and land use by human societies. The main driving force of these changes is the development of agricultural and forestry practices (Saunders et al. 1991). Thus, the percentage of crop area worldwide has increased 466% between 1700 and 1980, reaching 120 million km<sup>2</sup> of land converted to crops (Saunders et al. 1991). However, the majority of farmland was converted from forests. In the early 90's the Food and Agriculture Organization (FAO) estimated a consumption of 9 million hectares of forest per year and the value was increasing rapidly, suggesting that the world forest would be in danger.

The loss and fragmentation of habitat is a threat to biodiversity recognized by all (Foley et al. 2005) and is possibly one of the drivers of the sixth mass extinction (Wilcox and Murphy 1985). As such, in terms of biodiversity conservation, habitat destruction is among the top environmental concerns today. The literature on this subject is vast, and this topic has already been dissected repeatedly. Unfortunately the mechanisms underlying this effect are tricky to identify and understand, and is not always easy to clearly see the consequences of it on species (Debinski and Holt, 2000). In these circumstances it is appropriate to use strict definitions and techniques appropriate to determine such effect. There are some examples of that effect such as, according to BirdLife International, around 85% of threatened bird species and 86% of threatened mammal species are at risk due to habitat loss and degradation (in Baillie, et al. 2004). Likewise, a third of amphibian species is at risk of extinction, mainly due to habitat loss and fragmentation (Cushman, 2006).

In terms of biodiversity conservation, forest fragmentation is within the key environmental concerns (Lacy 1987, Haila 2002, Fazey et al., 2005). However, even though the literature on this subject is increasing (Fahrig 2003), the core mechanisms are not yet fully understood and the consequences are not fully identified (Bowne and Bowers 2004).

Debinksi and Holt (2000) suggest that several issues remain unresolved, including how the forest fragmentation affects dispersal and the daily movements of individuals, and how does that affect the genetic diversity of neutral alleles and traits linked to reproductive success. However, it is not always easy to demonstrate the effect of habitat fragmentation on species (Debinski and Holt, 2000).

Not only habitat loss but also fragmentation are generally thought to have negative effect on species perseverance (Trzcinski et. al., 1999, Fahrig and Merriam 1994). This is explained by the negative effect of fragmentation that comprises of an increase to the mortality of individuals travelling among patches and a reduction of the site's population size ensuing in increased vulnerability to extinction (Fahrig and Merriam 1994).

The lack of knowledge that exists about the relation between the effects of habitat fragmentation on populations of mammals in the top of the food chain, with the exception of studies regarding road construction (Kinnaird et. al. 2003) represents a major flaw in the outlook of population conservation. Therefore thorough knowledge of harmful factors to biodiversity should be the most important component of conservation planning for two major reasons. For one, conservation scheduling must function within the constraints of present and possible future land use alterations because altered land usually has low conservation worth, and areas with a higher probability of being altered are challenging for incorporating in reserve networks. And second, because the current and predicted magnitude of land transformation has repercussions for defining objective targets and for devising conservation plans (Margules and Pressey, 2000; Myers et al., 2000; Pressey and Cowling, 2001). Because conservation resources are scarce, there is an urgent need for identifying priorities for conservation actions.

### **The pine marten *Martes martes* L. 1758**

In the world, the genus *Martes* is constituted by eight species, and four of these species share the same subgenera as the pine marten: the stone marten *Martes foina*, the sable *Martes zibellina*, the Japanese marten *M. melampus*, and the American marten *M. americana* (Anderson 1970 in Caryl 2008). These five *Martes* species share many

morphological and ecological similarities and are found in habitats throughout the northern continents of the world (holarctic region) (Anderson 1970 in Caryl 2008).

The European pine marten is a medium-sized carnivore, with an elongate body, and has about the size and proportions of a large domestic cat. His head and body length is 44-58 cm and tail length is 15-29 cm. There is a clear sexual dimorphism with males weighing between 12 and 30% more than the females. The fur is a rich brown coat that is thick and silky in the winter and short and coarse in the summer. The coloration includes an irregular, creamy-orange throat patch, a grayish tint on the belly, and darkening on the paws. The tail is long and bushy and the ears are relatively large and triangular (Schwanz 2000). Pine martens have a predominantly carnivorous diet, consuming voles, mice, squirrels, rabbits, birds, and amphibians (Jedrzejewski et al. 1993, Baltrūnaitė 2002, Caryl 2008) but in some regions – Scotland – it has been recorded to include crabs, echinoderms, and barnacles (Gurnell et al. 1994). In the Scandinavian region, the pine marten is frequently categorized as a habitat specialist, because it is a species dependent on patches of old forest with possible denning and resting sites and that avoids open areas in order to be protected from predators, avoiding open areas such as agricultural fields. Other reasons for its dependence are the importance of thermal isolation and prey availability present in this type of habitat (Buskirk and Powell 1994, Brainerd 1990, Brainerd 2002). This occurs because it needs resting and denning sites and such needs are easier to have to fulfill on old growth forests where a greater presence of arboreal cavities exists (Zalewski 1997).

The pine marten is native to most of Europe, living in a diverse range of biotopes between the north of Europe (Finland, Scandinavia) and the south (Spain, Portugal), including the British islands and from Ireland and Great Britain to Iraq and Iran (Figure 1) (Proulx et al. 2004). The species is listed under Appendix III of the Bern Convention (Harris et al. 1995) although it can be hunted or trapped due the highly prized pelts on various European countries such as France, Germany and Sweden where there are large forested areas and marten populations are seen as stable (Proulx et al. 2004). There are a few countries where the marten is entirely protected due to the fact that its status is unknown or is believed to be vulnerable or threatened (Proulx et al. 2004).

In France the population size is not known. This species is distributed throughout the whole country and is supposedly regressing constantly over the centuries as a result of trapping, poisoning and forest fragmentation (Maurin, 1992).

But the primary reason for this decline is mainly for it being considered, by the Environment Ministry, “harmful to humans” (*Nuisibles*). During a brief hiatus between March of 2002, where it was removed of the list, and November of the same year the species was fully protected. But due to an uprising in the hunting community the species returned to the list and it can be hunted and trapped during the hunting period (Dragesco 1995).



Figure 1 – Distribution of the pine marten (*Martes martes*) in Europe and Asia

Some topics of the pine marten’s ecology as diet (Nyholm 1970, Garzon et al. 1980, Reig and Jedrzejewski 1988, Jedrzejewski et al. 1993, Clevenger 1993, Pulliainen & Ollinmaki 1996, Helldin 2000), home range (Zalewski et. al. 1995, Caryl 2008) and habitat associations have been dissected over the years, but our perception of the elements that limit marten density and distribution remain largely unexplained (Helldin 1998). The pine marten’s small size, somewhat evasive behavior and largely nocturnal habits in secluded habitats led to that it has been less intensively studied than other French carnivores as *Meles meles* (Henry 2004) and *Lutra lutra* (Defontaines 1999) but a few studies have been performed in the late 80’s (Marchesi 1989).



It is believed that the pine marten does not approach human homes, so any the number of domestic poultry caught by it cannot be very remarkable. A study by the National Office for Hunting and Wildlife (ONCFS) in cooperation with the Comité Interprofessionnel de la volaille de Bresse and the Fédérations Départementales des Chasseurs de Saône-et-Loire et l'Ain have shown that mustelids were responsible for only 2% of chickens killed or injured by predators (Dragesco 1995).

The ecological role filled by the species is very important and is quite diverse. It is mainly a predator, relying on small mammals for most of the year, but can complement its diet with carrion and/or vegetable materials. The diet characteristics such as what composes the diet and the percentage of each food item often change according to habitat conditions. Populations react to the random cycles of prey by drastically increasing their exploration of these prey items (Zalewski et. al. 1995). In some regions, such as Poland, fruits may never be eaten (Zalewski et. al. 1995, Clevenger 1993, Gurnell et. al. 1994) but in other areas in can fill over 30% of the marten's diet (Gurnell et. al. 1994). Discounting the seasonal boom of available rodents and fruits, the pine marten's diet is otherwise practically stable. Preferential foods include voles, other small mammals, birds, insects, carrion, and frogs, reptiles, and snails (Reig and Jedrzejewski 1988). Since in the winter resources are lower than in other times of the year, the pine marten stores its resources in arboreal cavities (Helldin and Lindstrom 1995). In habitats other than forest, all foraging is completed on the ground (Zalewski et al 1995, Helldin and Lindstrom 1995).

Therefore this species can cause a significant impact on the wildlife and thus the habitat and structure of their communities. Pine marten often play an ecological role that is disproportionately large compared to their numerical abundance. It is a species with many ecological needs and that leads to a low density (Overskaug et. al. 1994). Since it is a species that is almost on the top of the chain it has important roles in seed dispersal and even in pest control (Caryl 2008).

Due to such impact in the structure of animal communities and due to its high ecological needs we chose the pine marten to be our model in this study. Other reasons were because this was a species belonging to the CERFE's "small carnivore project" (CERFE - Centre de Recherche et de Formation en Eco-éthologie) so there was

previous work done with the species in this location, like scat collection, genetic confirmation of scat provenience, a PhD regarding the pine marten behavioral changes due to habitat fragmentation and the areas have also been used in studies to locate refuge and breeding places of European marten and the elaboration of census and home range of badger (*Meles meles*). Another reason we thought to be important for this choice was that, since the marten is on the top of an ecological chain, if we found that its food habits were affected by the forest fragmentation it could indicate that other species in lower stages of the ecological chain were also affected by the fragmentation. Finally due to the fact that this study may shows us how the local population subsists against a high percentage of habitat fragmentation.

A meticulous understanding of pine marten ecology within fragmented forest is necessary in order to formulate and execute informed decisions about how is the best way to administer this habitat for the advantage of the pine marten.

Fulfilling the food needs of the species is one of the fundamental issues of ecology. Several works have been made about the subject (Nyholm 1970, Reig and Jedrzejewski 1988, Clevenger 1993, Pulliainen & Ollinmaki 1996, Helldin 2000 among various others) but these works did not explore the habitat fragmentation subject which we did.

This is because the food is the main factor regulating populations and therefore, by studying the availability of food resources and how species take advantage of them we can use this information to help preserve species. Therefore we shall test the null hypothesis where diets from both sites are not different from one another.

## Objectives

Knowing how important specific food items are for the 'fitness' of the species is a major objective of studies on food habits (Livaitis 2000). Predators are animals that usually live in low densities, making it even more relevant to meet their food needs, especially for those who have higher energy requirements and depend on resources that fluctuate spatially and temporally (Caryl 2008). The overall objectives of this study were thus:

- To compare pine marten diet in a fragmented and a non-fragmented area, regarding especially the pine marten's basic resource - Rodents;
- To understand the results obtained within the general theme of forest management and conservation of pine marten;
- To speculate about resource availability, regarding the results.

## Materials and Methods

### Study site

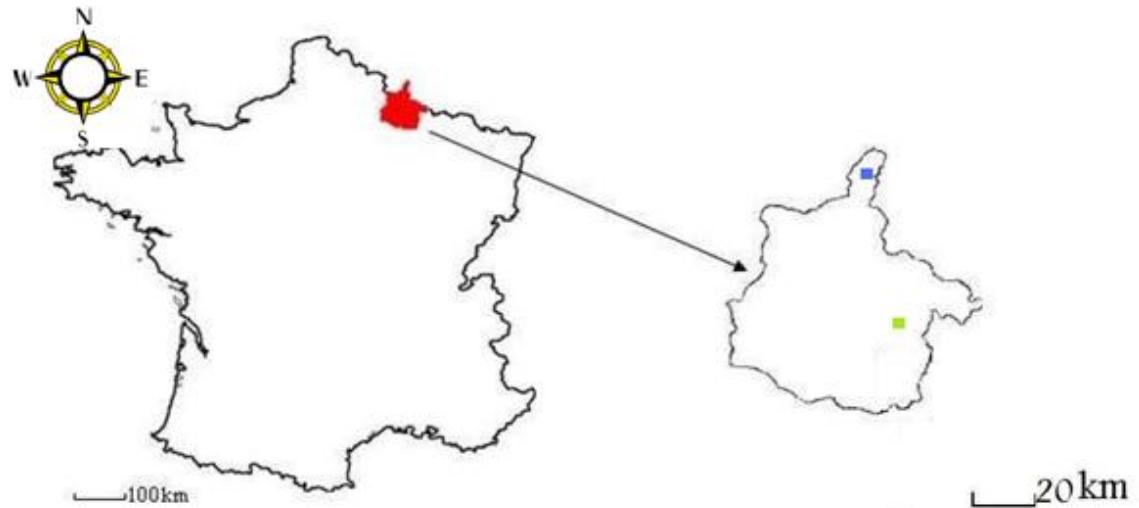


Figure 2 - The region of France that comprised both study sites and their respective location

The work was performed in the Ardennes region of France. The Ardennes is located in the northeast of France bordering the south of Belgium (Figure 2) and its climate is semi continental with long humid winters and big thermal amplitudes in the summer. The region's soil was formed by hercynian orogeny and it is friable and siliceous.

In the area two study sites of 6400 ha each were chosen: an area of fragmented forest and another of continuous forest. The first site (designated by NF – non-fragmented forest) is located in the northern most part right in the border between France and Belgium and the other in the southeast of the region 16 km east of Vouziers. It is characterized by the presence of an old-growth forest composed mostly of *Quercus* spp. and *Fagus sylvatica* and is located in the “Massif ardennais” that extends through Germany, Belgium and Luxembourg and varies in altitude between 150 and 700 meters; the altitude range of the study site varies within 290 and 450 meters. Regarding the second site (FF – fragmented forest), the area is generally composed of *Quercus* spp.,

*Fagus sylvatica* and *Picea abies* with a wide range of shapes and sizes interspread by agricultural terrains and small villages, and traversed by a few roads. It is located 60 km apart from the first site and it is appreciably more plain leading to a lower height range (160 to 220 meters).

There are several species of mammals present in both areas that include: badger (*Meles meles*), ermine (*Mustela erminea*), pine marten (*Martes martes*), weasel (*Mustela nivalis*), polecat (*Putorius putorius*), wild cat (*Felis silvestris*), fox (*Vulpes vulpes*), wild boar (*Sus scrofa*), roe deer (*Capreolus capreolus*), and a large number of rodent species.

### Field sampling

The field work was performed in November/December of 2009 and March/April of 2010. A transect of 2 km was performed in each of the 16 squares of 2 km<sup>2</sup>. In each square, the transect was established covering woodland (Figure 3) because “martens

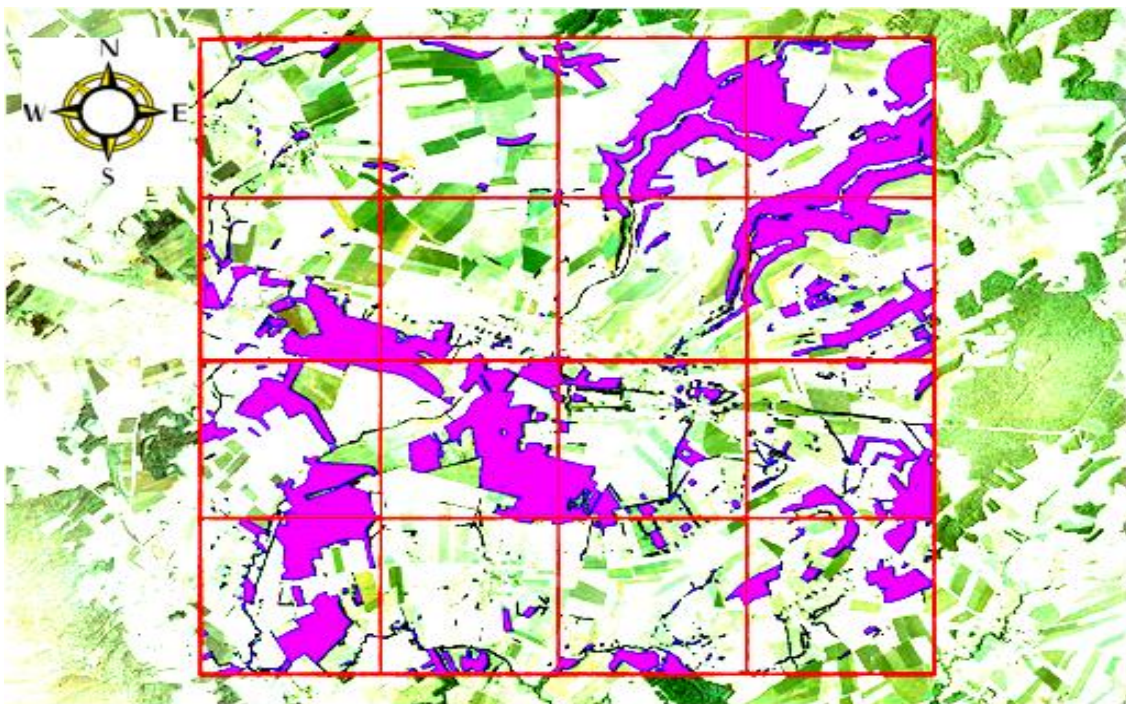


Figure 3 - The fragmented forest area (Ardennes region near Vouziers) with the woodland cover

are likely to concentrate their activity in woodland” (Balharry 1993). The classification of “woodland” was defined in ArcView 3.2 by a specialist with terrain knowledge. Each

transect was made by 2 people to allow a more thorough coverage of the trail and increase the probability of collecting a larger sample of scats.

For each scat found we registered the number of the transect, the date and the exact location (UTM coordinates) in which it was collected. For a preliminary assessment of the species originating the scat we looked at the size, shape, smell and location on which we had found it. Pine marten's scats are characterized for being small, thin and having a twist in the tip (Velandier 1983, Bright and Harris 1994, Bright et al. 1995), they also have a very inconspicuous smell and they are usually located in roads, dead wood and on top of rocks (Balharry et. al. 1996). Scats were further stored in freezers to prevent the degradation of DNA.

They were then sent to the laboratory on the University of Lyon for species identification using molecular markers.

No transects were performed on or in the first two days after rainy or snowy events because the scats could have been washed or could have been covered by snow.

### **Diet analysis**

The diet analysis occurred between November of 2010 and April 2011. Encompassing all transects, 363 droppings were found and 139 were tested positive as pine marten. Of the 139 scats, 104 were from the fragmented area and 35 from the non-fragmented area. Only the scats that were positively identified as pine marten were analyzed to assess the species feeding habits.

Each scat was placed in hot water and stirred to dissolve the mucilaginous substances that involved it to provoke the breakdown of various not digested elements (Zalewski 2004). The elements resulting from the previous procedure were filtered in a 0.5 mm sieve mesh.

The identification of remains was conducted using feathers for birds and chitin shells for insects. The identification of mammal species was based in the microscopic examination of teeth associated with the microscopic examination of cross-section of hair (plate method) used to identify rodents by comparison to the characteristics (Debrot et al. 1982, Erôme and Aulagnier 1982).



Prey were categorized into five classes according to the remains found: “Rodents”, “Birds”, “Seeds”, “Insects” and “Other mammals”. Other mammals were put in separated category which included carrion (large or semi-large mammals) and insectivores. The “seeds” category does not include other type of vegetation remains. Results were expressed in terms of relative occurrence by dividing the number of scats in which the prey item occurred with the total number of scats analyzed.

The different categories of prey were classified regarding their importance in the food spectrum using the criterion used by Skuratowick (1950 in Farinha, 1995), ergo based on the percentages of occurrence:

- $PO > 20\%$  basic resource;
- $PO \leq 20\% > 5\%$  constant resource;
- $PO \leq 5\% > 1\%$  complementary resource,
- $PO \leq 1\%$  occasional resource.

### Diet comparison

In order to test if the pine marten diet is different between continuous and fragmented areas, we used Fischer exact test due to the fact that the data did not fill the assumption of the chi-square test (Krebs, 1999) that the sample size should be big enough so that the expected count in each cell is greater than or equal to 5. It was made in two steps: first to test using all food categories and to test only species included in the “Rodents” category. Therefore our null hypothesis is that the diets of both sites are not different from one another.

The second test was performed using the items *Myodes glareolus*, *Apodemus sylvaticus*, *Microtus* sp. and Other Species. We also used the same method to test the similarity in the “Rodents” category between sites.

If our null hypothesis was not rejected we then did a third test in which we ascertained if the proportion of “Rodents” was homogenous, in other words if there were any prey items favored by the pine marten. The analysis was then done through a chi-square test. Data analysis was performed using the software STATISTICA 7.0.

To complement the earlier results and to evaluate the amplexness of the resource exploitation, we did a statistical comparison of the food niche breadth of the pine

marten using the Shannon-Wiener's index of niche breadth ( $H'$ ) (Krebs 1999). Calculations were based on frequency of occurrences of the five food categories, according to the following formula:

$$H' = -\sum p_i (\log p_i)$$

where " $H'$ " represents the diet breadth, and " $p_i$ " is the proportion of the diet formed by species " $i$ ". The standardization of this index ( $J'$ ) was done using the formula:

$$J' = H' / \log n$$

where " $n$ " is the number of food types. Standardized values vary between 0 and 1, with low values indicating a narrow niche breadth i.e. dietary specialism and high values indicating wider niche breadth i.e. dietary generalism (Krebs 1999).

We then compared the calculated values of niche breadth for both sites using a t-test:

$$T = (H'_{NF} - H'_{FF}) / S_{H'_{NF} + H'_{FF}}$$

where " $s$ " is the niche breadth variance.

Finally we used the Pianka's index (Pianka 1973 in Krebs 1999) to see how both niches overlap. This index's value varies between 0 and 1 and reaches its maximum value when there is a total overlapping of the niches. We also did a complementary calculation of the Pianka's index without the "Seeds" category since there were no items of this category on the non-fragmented forest site's scats.

## Resource exploration

In order to know if the pine marten went outside of its preferential habitat with the purpose of feeding, we performed the data analysis considering only the FF site. In this analysis we separated the scats through bibliography consultation, according to the items present that belonged to the "Rodents" category. We created 2 groups using their



habitat preferences as differentiator since we could pinpoint in which habitat the pine marten had captured its prey. We joined the scats that contained *Myodes glareolus*, *Arvicola terrestris* and *Muscardinus avellanarius* together in the woodland group and *Apodemus sylvaticus*, *Microtus* sp., *Mus musculus* and *Rattus* sp. in the other habitats group (non-woodland). The reason for the non-inclusion of the NF site was due to the non-existence of fragmentation leading to the inability of using habitat as a differentiator between groups.

Using the percentage of woodland cover in the FF site calculated with ArcView 3.2, we then ascertained the expected number of scats from each habitat (woodland and non-woodland) if the habitat usage by pine martens would be equal throughout the study site.

We did a chi-square test in order to compare the number of scats found in each habitat type with the expected number.

## Results

### Diet analysis

We found traces of 7 genera of rodents in the scats: *Myodes*, *Apodemus*, *Arvicola*, *Microtus*, *Rattus*, *Muscardinus* and *Mus*. Since some of the genera had more than one species present in the study area we joined the various species due to their similar habitats and due to the fact that their distinction based only on hair and teeth is very difficult. The species we joined were *Microtus arvalis* and *Microtus agrestis* in one case and *Rattus norvegicus* and *Rattus rattus* in another (Table 1). The other mammals

Table 1 – Composition of the food spectrum of pine marten, including number of occurrences of each food item and its frequency of occurrence (F.O)

	FF site		NF site		Total (n)
Rodents	n	F.O.	n	F.O.	
<i>Myodes glareolus</i>	35	0,25	9	0,23	44
<i>Apodemus sylvaticus</i>	19	0,13	3	0,08	22
<i>Arvicola terrestris</i>	3	0,02	2	0,05	5
<i>Microtus</i> sp.	8	0,06	4	0,10	12
<i>Rattus</i> sp.	2	0,01	1	0,03	3
<i>Muscardinus avellanarius</i>	1	0,01	0	0	1
<i>Mus musculus</i>	1	0,01	0	0	1
Rodents NI	0	0,00	1	0,03	1
Other mammals	1	0,01	2	0,05	3
Other prey					
Birds	42	0,29	13	0,33	55
Seeds	16	0,11	0	0,00	16
Insects	15	0,10	4	0,10	19
Total	143	1	39	1	

category included one *Ondatra zibeticus*, one *Capreolus capreolus* and one *Sorex* sp..

Bird remains were comprised of mostly digested feathers but we also found some scats with one undigested bird paw and a few claws. The remains were too digested for us to identify families or genus except for undigested paw which belonged to a member of the *Passeriformes*. With regard to the seeds we identified two species: *Rosa canina* L. and *Prunus avium*. Lastly with insects we just noted the presence of traces in a total of 19 scats always with other items in the scat.

The category “Seeds”, the fourth category regarding percentage of occurrence, was only present in the FF site.

### Diet comparison

The rodents’ category, heavily represented in the diet of the study area, was classified according to the bibliography consulted (Jedrzewski et. al. 1993, Caryl 2008). Since they represent a high percentage of occurrence, 49% in the fragmented forest site and 52% in the continuous forest site (Figure 4), and following the Skuratowicz criteria (1950, in Farinha, 1995) this prey category is considered a basic resource (Table 2). Birds are also considered basic resources showing high percentages of occurrence in the different sites, 29 and 33% respectively. These two categories represent a total of 78 and 85%.

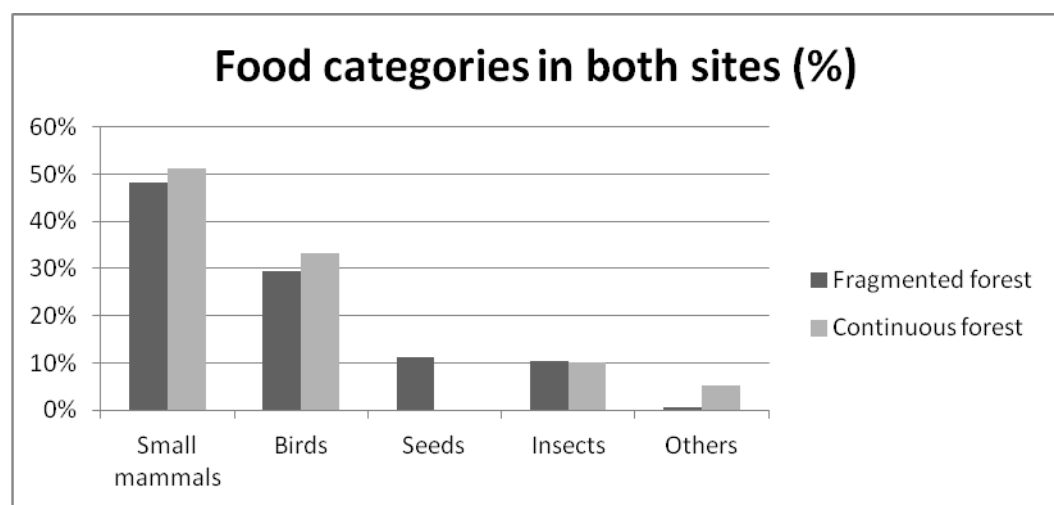


Figure 4 – The percentage of occurrence of each food category within both sites

Table 2 – Classification of resources in the food spectrum.

	NF site	FF Site
<b>Rodents</b>	<b>Basic resource</b>	<b>Basic resource</b>
<b>Other Mammals</b>	<b>Complementary resource</b>	<b>Complementary resource</b>
<b>Birds</b>	<b>Basic resource</b>	<b>Basic resource</b>
<b>Insects</b>	<b>Constant resource</b>	<b>Constant resource</b>
<b>Seeds</b>	<b>-</b>	<b>Constant resource</b>

The insects were the third most common identified category and occurred in, approximately, 11% of all the scats analyzed showing very similar percentage of occurrence values on both sites.

The “Other mammals” category included carrion and comprised less than 2% of the total of items found (3 in 179 total items found in scats).

Regarding the comparison of diets between sites the results of the Fischer exact tests showed a  $p=0,175$  with respect to all food categories and a  $p=0,373$  when considering only the “Rodents” category showing that our null hypothesis of the equality of the diets is true.

When testing our data for the null hypothesis of a similar proportion of each element of the “Rodents” category present in the scats we found clear differences through a chi-square test ( $p < 0,001$ ).

So in order to have a better understanding of the pine marten diet regarding one of its basic resources we built a chart containing the data from both areas where every species in the “Rodents” category was discriminated by percentage of occurrence (Figure 5).

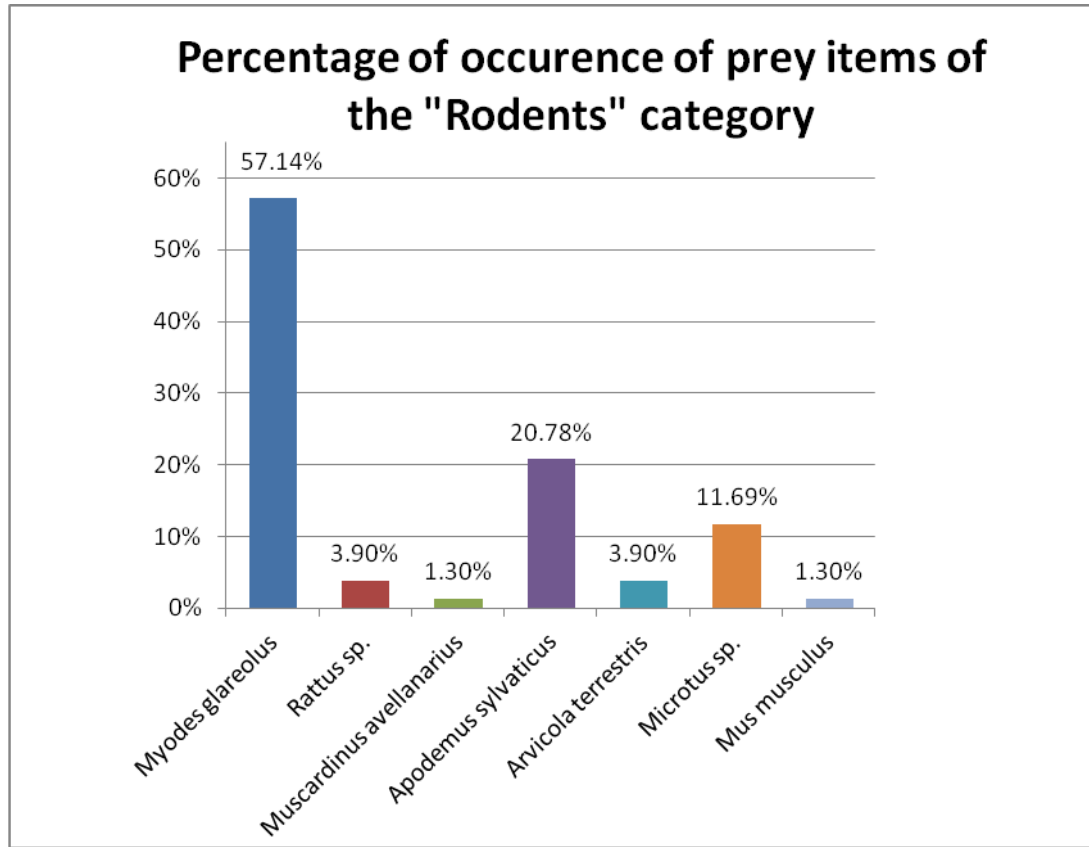


Figure 5 – Rodents found in pine marten scats

In the chart above, we can perceive that *Myodes glareolus* is evidently the most consumed item with over half of the total number of rodent traces found in the scats. Representing one fifth of the total number of items found in this category is *Apodemus sylvaticus*.

The third most consumed item was *Microtus sp.* signaling that is a constant presence in pine marten diet. The last four items in this category differed very little from each other and comprised little above 10% of the total items (8 in 77).

The Shannon-Wiener index calculated to complement the previous results showed values close to 1 in both areas (Table 3) which mean that the pine marten has a wide niche breadth reinforcing the generalist character previously referred. The difference between values calculated by a t-test is not significant ( $t=1,88$ ,  $0,10 > p > 0,05$ ,  $d.f.=17$ ).

Table 3 – The Shannon-Wiener index in both sites

Standardized Shannon-Wiener index (FF site)	Standardized Shannon-Wiener index (NF site)
0,775806522	0,847231544

The Pianka's index shows a very high food niche overlap between sampling sites, with a value of almost 1 (complete food niche overlap) (Table 4).

Table 4 - Niche overlap between sampling sectors

Pianka's Index	FF Site /NF Site
	0,97857175

## Resource exploitation

The expected number of scats that contained prey items from the “Rodents” category of habitat type (woodland forest and non-woodland forest), in accordance with its habitat representativeness in the site, was of 14 scats for the woodland area (1267 ha – 20%) and 55 (5133 ha – 80%) for the non-woodland area, for a total of 69 scats containing “Rodents” from the FF site. The real number of scats found that belonged to each habitat was of 39 from the woodland area and 30 from the non-woodland area (Table 5).

Table 5 – Real number of scats attributed to each habitat

Woodland		Non-woodland	
<i>Myodes glareolus</i>	35	<i>Apodemus sylvaticus</i>	19
<i>Arvicola terrestris</i>	3	<i>Microtus sp.</i>	8
<i>Muscardinus avellanarius</i>	1	<i>Rattus sp.</i>	2
		<i>Mus musculus</i>	1
<b>Total</b>	<b>39</b>	<b>Total</b>	<b>30</b>

The result from the chi-square test is presented in Table 6.

Table 6 – Chi-square test's result between the expected and the real number of  
scats from each habitat

Chi-square test	
Value	56
<i>p</i>	0,000*

## Discussion

Since food is the main factor that regulates animal populations (Litvaitis 2000), this study focused on the variation in pine marten diet, especially in the consumption of rodent prey and how the human-induced changes in the habitat affects this crucial element in pine marten ecology. This is crucial to understand due to the higher degree of forest fragmentation in France and, especially in the Ardennes' region.

The pine marten's diet varies according to habitat type, altitude, season years, the biogeography of prey species, the stability of ecosystems and prey availability (Jedrzejewski et. al 1993, Zalewski 1995, Sidorovich 2005, Mergey 2007, Caryl 2008).

The availability of prey influences the ecology of the pine marten, regulating their home range, habitat use and dispersal, being therefore considered a species considered food-limited (Putman 2000, Proulx et. al. 2004). In Europe there is a great variability of the pine marten diet, namely between marten population in Poland, France and Scotland (Marchesi and Mermod 1989, Jedrzejewski et. al. 1993, Caryl 2008).

Thus, at a time when it is known that increasing human activities on forest systems are causing a major loss of available habitat, how the pine marten responds to these variations have a high importance. Only then can we see if the species is adapting to the modified habitat, and possibly prey availability changes or if these changes are, or are likely to compromise viability of the species (survival and reproduction).

In these systems, it is known that rodents are more frequent in pine marten diet and there are a greater number of rodent species consumed as well as a greater diversity (including fruits, carrion and insects) in forest habitats than in other habitats (Lockie 1961, Jedrzejewski et. al. 1993). In addition, positive selection is known to the some genus such as *Microtus* voles (Caryl 2008), *Myodes* and *Apodemus* (Marchesi and Mermod 1989).

## Habitat fragmentation

The habitat changes are reflecting in the pine marten diet. The results we obtained show that the most consumed species (in percentage of occurrence) are those that we knew were present in forest-type habitats but a noteworthy quantity of non-forest species were also found in our analysis.



The primary difference noted in the pine marten diet when comparing habitats is the complete absence of seeds in scats collected in the continuous forest site, with all remaining prey categories in similar values leading to a very analogous food niche size.

The two identified species of plants exist in somewhat different habitats: *Rosa canina* is present on roadsides, shrubs and on the edge of woodland while *Prunus avium* is usually located on the inside border of the forest and the edge of it (Blamey and Grey-Wilson 1989). As the consumption of seeds was only found in the FF site and knowing that one species is not present in woodland habitat and the other is usually present on the edge of forest due to its ecological needs regarding sunlight (Blamey and Grey-Wilson 1989), we can say that this is a resource explored by the pine marten diet outside of its natural habitat. Supporting this is the classification of these two species as non-present in woodland habitats made by Marchesi and Mermod (1989). With this, and unlike other works consider (Zalewski et. al. 1995, Sidorovich et. al. 2005, Kranz et. al. 2008), we can claim that the pine marten feeds regularly outside of its habitat. The additional needs of other food sources may indicate the quantity of rodent and bird prey is not enough to fill the pine marten's needs. This shows that, the pine martens, although preferring the woodland habitat to hunt, adapt to a food constriction by exploring other resources.

Taking into account the results that this work shows we see that *Myodes glareolus* is the most consumed prey item within the rodents found. We can also perceive that even when there is a high habitat fragmentation (almost 80%) the preferred pine marten prey (Marchesi and Mermod 1989) still constitutes an important part of its diet.

What we can also discuss about is the quantity of carrion that a marten has access to in a vast area of forest although our sampling is not nearly big enough to evidently state anything regarding this subject. We see that in the NF site, 2 scats clearly contained carrion due to the prey's size (*Capreolus capreolus* and *Ondatra zibethicus*) and that in the FF site there was no carrion found in any of the 104 scats analyzed. If a larger number of scats were analyzed from the NF site maybe carrion could appear in a larger quantity of scats.

If habitat fragmentation leads to a low cover of forest, pine marten populations must adapt or they will disappear as demonstrated by Proulx et al. (2004) in the British Islands case. In this case they found denning sites not in the forest but in holes found in

cliffs near the ocean and adapted their diet to a less-rodent type while they used their foraging abilities on mollusk. In our study the results indicate that even though there is a high percentage of habitat fragmentation the pine marten's diet still remains similar to that of other populations in the same region (Marchesi and Mermoud 1989) and therefore indicates an adapted pine marten species to habitat contraction.

There is increasing verification that mustelids suffer from intraguild predation by bigger carnivores, which may possibly be prevalent in fragmented habitats (Brainerd et al. 1994). But our results show that the pine marten is well adapted to habitat fragmentation. This does not invalidate the fact that it may face a big threat as a result of habitat loss: fragmentation effects (Bright 2000).

Habitat fragmentation has a negative effect on species that are considered to be habitat-specialists such as the pine marten, and favorably discriminates those that can take advantage of the anthropogenic conditions between human-tainted habitats (Bright 2000). The repercussion of the pine marten's unwillingness to cross zones without cover (Smith and Schaefer 2002) is that the amount and allocation of forest patches affects the intensity with which they are explored (Hargis et al. 1999). Even big forest patches may not be utilized if they are very parted from other appropriate habitat patches (Hargis et al. 1999). This might explain the consumption of fruits from trees that our results show in the FF site, since these two species are usually on the edge of woodland habitat. Forests ought to therefore be managed at the landscape extent to guarantee that connectivity linking forest patches is maintained, but thorough comprehension of marten habitat requirements is needed with the purpose of achieving this.

### **Data limitations**

The sample sizes used in dietary studies are usually too little to allow general conclusions about the species' diet to be reached (Balharry 1993a). Despite this, several dietary studies were supported by small sample sizes of scats (Putman 2000, Caryl 2008). As sample scat's sizes are reduced, the value of variance increases to a high value, often becoming too big for estimates to be meaningful (Carss & Parkinson 1996). In this work the amount of scats was

better than in other studies (Caryl 2008) but it should be even greater especially in the NF site where the number of scats is very little.

Since the number of scats found and analyzed from the continuous forest site was considerably smaller than that of the fragmented forest site (a proportion of almost 5 to 1) this lead to a diet comparison far less robust then it should have been. This could also lead to the absence of certain food items (rarest prey) in the pine marten's diet in that site. Although we don't think that there is a higher density of pine marten in the fragmented habitat, the difference observed is noteworthy and is probably the easiness to found scats in a less dense type of forest. In fact, in the FF site, the denning and resting places were easier to find. This resulted in a larger amount of scats collected in the surroundings of such sites than in sites where we did not know such locations. Since the continuous forest site had a dense forest cover these places were much harder to encounter by chance. As an example one of the possible outcomes if we had found and analyzed more scats from the NF site we could discern carrion as a major food source in this site.

Regarding the "insects" category one should note that there could be an overestimation of these values due to them being a result of involuntary ingestion (direct or through feeding on insectivore preys).

The orography of the NF site might also have played a particular role in this difference between the scats found on each site because it was hilly, making it harder to find scats in the steep slopes and under denser vegetation. Another factor was the absence of fallen trees in this site which we found to be, as well as other authors (Clevenger 1993, Bright and Harris 1995), a preferable place to defecate for the pine martens.

One final limitation about our work had was the fact that we did not identify bird species, like it was done in other similar works, that could give us information on possible effects of habitat fragmentation in this essential resource in the diet of pine marten.

### **Future implications for the preservation of pine marten habitat**

The conclusions presented here are in accordance with those of Brainerd et al. (1994) are likely to recommend that the pine marten is a species with a larger adaptable

capacity than previously believed. While the presence of some structural components of old-growth forests is essential for pine marten, a high proportion of old-growth forest in the landscape is probably not (Brainerd et al. 1994). With the results of this work we can say that the pine marten shows adaptation to highly fragmented habitats and that it will use open areas that provide adequate structure as protective cover or food resources. Indeed the structural conditions that non-forest habitats provide probably allow the pine marten to inhabit areas without a significant level of forest habitat (Balharry 1993a). Therefore the importance of transitional habitats, which offer pine marten with essential physical structure cover, should not be undervalued. Consequently since our FF site had 80% non-woodland cover we can perhaps speculate that the agricultural fields and shrub canopy present on the site provided the protective cover mentioned above in order for the pine martens to cross from one forest patch to another without being totally exposed to predators. These structures are vital for linking larger forest fragments, in which the pine martens rest, even though they cannot substitute continuous extents of forest.

As for measures that could lead to the preservation of pine marten we can refer the management of old-growth forests within young succession stages, since it could favor generalist predators by rising the total of areas with grass-dominated foliage that are fit habitat for their favored prey, *Microtus* voles and *Myodes glareolus* (Marchesi and Mermod 1989, Caryl 2008) although this should not be done recurrently because then we could be endangering the species. More specifically the old-growth forests should be managed in order to become a more heterogeneous habitat which would benefit the marten due the several prey species and denning and resting sites that would likely appear that in a homogenous habitat.

One other measure is to study the landscape use by pine martens in a highly fragmented habitat in order to maximize conservational efforts, regarding which patches (regarding shape, size and characteristics) are essential to the species. It is important to characterize those patches regarding the two most vital factors in pine marten conservation: the existence of denning and resting sites and prey availability. Knowing the ecological needs of the populations is taking one step further to every species' conservation.

## **Concluding remarks**

Throughout the duration of this study it became evident that public opinion regarding the pine marten in France was generally of two natures: absent or negative. The species was described as almost a “pest” consuming resources that, by public opinion, should be consumed by other game species. These opinions are indefensible, stressing the public’s ignorance surrounding marten’s dietary habits and population densities.

Since public perception is erratic, it can be changed through positive publicity and education. News stories about the potential for pine marten to act as implements of biological control, preferentially preying upon rodent species should be a good way to change the public’s view of the pine marten. Another way of doing this is exposing the benefits of the species regarding game species. This would be a key move on countryside regions which are the majority of people viewing the pine marten in a negative fashion. Thankfully this will improve the public-researchers relation for a more cordial one allowing a more efficient and focused work with the public’s encouragement. A good example of this is the pine marten’s conservation case in Scotland where the species was brought back from a state of nearly extinct and now its numbers have increased as well as its distribution. This was accomplished by protective legislation and land management only possible due to a positive public perception regarding the species’ conservation.

## Bibliography

Balharrry, D., 1993a. Factors affecting the distribution and population density of pine martens (*Martes martes* L.) in Scotland. PhD Dissertation, University of Aberdeen, Aberdeen, UK.

Balharrry, D., 1993b. Social organization in martens: an inflexible system? Symposia of the Zoological Society of London, 65: 321-345.

Balharrry, E. A., McGowan, G. M., Kruuk, H., Halliwell E., 1996. Distribution of pine martens in Scotland as determined by field survey and questionnaire. Scottish Natural Heritage, Edinburgh, UK. SNH Survey and Monitoring Report No. 48.

Baltrunaite, L. 2002. Diet composition of the red fox (*Vulpes vulpes*), pine marten (*Martes martes* L.) and racoon dog (*Nyctereutes procyonoides* Gray) in clay plain landscape, Lithuania. *Acta Zoologica Lituanica*, 4: 362-368.

Blamey, M., Grey-Wilson, C., 1989. *Flora of Britain and Northern Europe*. Hodder & Stoughton, 133-144.

Bowne, D.R., Bowers, M.A., 2004. Interpatch movements in spatially structured populations: a literature review. *Landscape Ecology* 19: 1-20.

Brainerd, S.M., Helldin, J.O., Lindstrom, E., Rolstad, J., 1994. Eurasian pine martens and old industrial forest in southern boreal Scandinavia. In S.W. Buskirk, A.S. Harestad, M.G. Raphael & R.A. Powell (Eds.) *Martens, sables and fishers: biology and conservation*. Cornell University Press, London, UK. 343-354.

Brainerd, S.M. & Rolstad, J. 2002. Habitat selection by Eurasian pine martens *Martes martes* in managed forests of southern boreal Scandinavia. - *Wildlife Biology* 8: 289-297.

Brainerd, S.M., 1990. The pine marten and forest fragmentation: a review and synthesis. In: Myrberget, S. (Ed.); Transactions of the 19th IUGB Congress. Trondheim, Norway, 421-434.

Bright, P. W., Harris, S., 1994. Reintroduction of the pine marten: feasibility study. University of Bristol, Bristol, UK. English Nature Contract Report F72-11-10.

Bright, P. W., Harris, S., 1995. Determining the minimum woodland area requirements to sustain pine marten populations. In Initiating a Recovery Programme

for the Pine Marten in England and Wales. People's Trust for Endangered Species, London, UK. 7-15

Bright, P.W., 2000. Lessons from lean beasts: conservation biology of the Mustelids. *Mammal Review*, 30: 217-226.

Buskirk, S.W., Powell, R.A., 1994. Habitat ecology of fishers and American martens. in S.W. Buskirk, A.S. Harestad, M.G. Raphael & R.A. Powell (eds.) Martens, sables and fishers: biology and conservation. Cornell University Press, London, UK. 283-296.

Caryl, F. M., 2008. Pine marten diet and habitat use within a managed coniferous forest. Ph.D. Thesis. School of Biological & Environmental Sciences. University of Stirling.

Clevenger, A.P., 1993. The European pine marten *Martes martes* in the Balearic Islands, Spain. *Mammal Review*, 23: 65-72.

Clevenger, A.P., 1994. Habitat characteristics of Eurasian pine martens *Martes martes* in an insular Mediterranean environment. *Ecography*, 17: 257-263.

Debrot, S., Fivaz, G., Mermoud, C., Weber, J., 1982. Atlas des poils de mammifères d'Europe. Institut Zoologique de l'Université de Neuchâtel, Neuchâtel.

Defontaine P., 1999. Répartition de la Loutre *Lutra lutra* dans le sud-est du Massif Central. *Bièvre*, 16: 13-26.

Debinski, D., Holt R., 2000. Habitat fragmentation experiments: a global survey and overview. *Conservation Biology* 14: 342-355.

Dragesco, E., 1995. *La vie sauvage dans les ALPES*. Edition Delachaux et Niestlé.

*Endangered Species Act, The (ESA)*, 1973. 16 USC, Sections 1531–1543.

Erôme, G., Aulagnier, S., 1982. Contribution à l'identification des proies des rapaces. *Bièvre* 4: 129–135.

Fahrig, L., Merriam G., 1994. Conservation of fragmented populations. *Conservation Biology* 8: 50-59.

Fahrig, L., 2003. Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology, Evolution and Systematics* 34: 487–515.

Farinha, N., 1995. Distribuição e Ecologia da lontra (*Lutra lutra* Linnaeus, 1758) no Parque Natural de Montesinho. Relatório Técnico. Parque Natural de Montesinho / Instituto da Conservação da Natureza, Lisboa.

Fazey I., Fischer J., Lindenmayer D.B. 2005. What do conservation biologists publish? *Biological Conservation* 124: 63-73.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N., Snyder, P.K., 2005. Global consequences of land use. *Science*, 309: 570–574.

Franklin, J.F., 1993. Preserving biodiversity—species ecosystems or landscapes? *Ecological Applications* 3: 202–205.

Garshelis, D.L., 2000. Delusions in habitat evaluation: measuring use, selection, and importance. In Boitani, L. and Fuller, T.K., eds. *Research techniques in animal ecology: controversies and consequences*. NY: Columbia University Press. 111-164.

Garzon, J., Ballarin, I., Cuesta, L. & Palacios, F. 1980. Datos preliminares sobre la alimentación de la marta comun (*Martes martes* L. 1758) en España. II Reunión Iberoamericana de Conservación y Zoología de Vertebrados, Cáceres.

Gurnell, G., Vennig T., Maccaskill B., Maccaskill D., 1994. The food of pine martens (*Martes martes*) in West Scotland. *Journal of Zoology* (London), 234: 680-683.

Haila, Y., 2002. A conceptual genealogy of fragmentation research: from island biogeography to landscape ecology. *Ecological Applications* 12: 321-334.

Hargis, C.D., Bissonette, J.A., Turner, D.L., 1999. The influence of forest fragmentation and landscape pattern on American marten. *Journal of Applied Ecology*, 36: 157-172.

Harris, S., Morris, P., Wray, S. & Yalden, D. 1995. A review of British mammals: population estimates and conservation status of British mammals other than Ceteceans. Joint Nature Conservation Committee, Peterborough.

Helldin, J.O., 1998. Pine marten (*Martes martes*) population limitation: Food, harvesting of predation? PhD Thesis, Swedish University of Agricultural Sciences, Upsala, Sweden.

Helldin, J.O., 2000. Seasonal diet of pine marten *Martes martes* in southern boreal Sweden. *Acta Theriologica* 45: 409-420.



Henry, C., 1984. Eco-éthologie de l'alimentation du blaireau européen (*Meles meles* L.) dans une forêt du centre de la France. *Mammalia*. 48, 4: 489–504.

Jedrzejewski, W., Zalewski A., Jedrzejewski, B., 1993. Foraging by pine marten *Martes martes* in relation to food resources in Bialowieza National Park, Poland. *Acta Theriologica*. 38, 405 – 426.

Kinnaird, M., Sanderson E., O'Brien T., Wibisono H., Woolmer G., 2003. Conservation Biology Deforestation Trends in a Tropical Landscape and Implications for Endangered Large Mammals. *Conservation Biology*, 17: 245–257.

Kranz, A., Tikhonov, A., Conroy, J., Cavallini, P., Herrero, J., Stubbe, M., Maran, T. & Abramov, A. 2008. *Martes martes*. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. <www.iucnredlist.org>.

Krebs, C.J., 1999. *Ecological Methodology*, 2nd edition. Addison-Wesley Educational Publishers, Inc., New York.

Lacy, R., 1987. Loss of genetic diversity from managed populations: interacting effects of drift, mutation, immigration, selection, and population subdivision. *Conservation Biology* 1: 143-158.

Levy, P. S., Lemeshow S., Hade, E. M., Ferketich, A. K., 1991. Sampling of populations: methods and applications, New York, NY: Wiley-Interscience publication

Livaitis, J.A., 2000. Investigating food habits of terrestrial vertebrates. In Boitani, L. and Fuller, T.K., eds. *Research techniques in animal ecology: controversies and consequences*. NY: Columbia University Press. 165-190.

Lockie, J. D., 1961. The food of the pine marten (*Martes martes*) in West Ross-shire, Scotland, *Proceedings of the Zoological Society of London*, 136: 187-95.

Macdonald, D. W., Barrett, P., 1993. *Mamíferos de Portugal e Europa*. Guias FAPAS, Porto.

Macdonald D., Barrett P., 1995. *Guide complet des Mammifères de France et d'Europe*. Ed. Delachaux et Niestlé, Lonay.

Marchesi P., 1989. Ecologie et comportement de la martre (*Martes martes* L.) dans le Jura suisse. Thèse Université de Neuchâtel, Suisse.

Marchesi, P., Mermoud C., 1989. Régime alimentaire de la martre (*Martes martes* L.) dans le Jura suisse (Mammalia: Mustelidae). *Revue Suisse Zoologie*. 96: 127-46.

Margules, C.R., Pressey, R.L., 2000. Systematic conservation planning. *Nature* 405, 243–253.

Mathias, M. L., Santos-Reis, Palmeirim, J., Ramalhinho M. G., 1998. *Mamíferos de Portugal*. Edições INAPA.

Maurin, H., 1992. Inventaire de la faune de France : vertébrés et principaux invertébrés. Muséum National d'Histoire Naturelle, Nathan.

Mergey, M. 2007 Thesis: Réponses des populations de martres d'Europe (*Martes martes*) à la fragmentation de l'habitat: mécanismes comportementaux et conséquences. Thèse de Doctorat. Université de Reims Champagne-Ardenne, France.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots conservation priorities. *Nature* 403: 853–858.

Nyholm, E.S. 1970. On the ecology of pine marten (*Martes martes*) in eastern and northern Finland, *Soumen Riista* 13: 57-64.

Overskaug, K., H. Broseth, B. Knutsen. 1994. Area and habitat use of pine martens, *Martes martes*, in mid-Norway. *Lutra*, 37: 81-88.

Pressey, R.L., Cowling, R.M., 2001. Reserve selection algorithms and the real world. *Conservation Biology* 15, 275–277.

Powell, R.A., 1994. Structure and spacing of *Martes* populations. In: Buskirk, S.W., Harestad, A.S., Raphael, M.G., comps., eds. *Martens, sables, and fishers: biology and conservation*. Ithaca, NY: Cornell University press. 101-121.

Proulx, G., Bryant, H. N.; Woodard, P. M., eds. 1997. *Martes: Taxonomy, ecology, techniques and management*. Edmonton, Alberta, Canada. Provincial Museum of Alberta, 265-278.

Proulx, G., Aubry, K., Birks, J. Buskirk, S., Fortin, C., Frost, H., Krohn, W., Mayo, L., Monakhov, V., Payer, D., Saeki, M., Santos-Reis, M., Weir, R. & Zielinski, W., 2004. World distribution and status of the genus *Martes* in 2000. in D. J. Harrison, A. K. Fuller and G. Proulx, eds. *Martens and Fishers (Martes) in Human-Altered Environments*. Springer US, New York. 21-76.

Pullianen, E., 1980. Winter habitat selection, home range, and movements of the pine marten, Worlwide Furbearer Conference proceeding, 2: 1068-1087.

Pulliainen, E. & Ollinmaki, P., 1996. A long term study of the winter food niche of the pine marten *Martes martes* in northern boreal Finland. *Acta Theriologica*, 41: 337-352

Putman R. J., 2000. Diet of pine martens *Martes martes* L. in west Scotland, *Journal of Natural History*, 34, 5: 793-797

Reichholf, J., 1983. *O Mundo da Natureza – Mamíferos*. Editorial Pública.

Reig, S. & Jedrzejewski, W., 1988. Winter and early spring food of some carnivores in the Bialowieza National Park, eastern Poland. *Acta Theriologica*, 33: 57-65.

Rojas, M., 1992. The species problem and conservation: what are we protecting? *Conservation Biology* 6, 170–178.

Rosalino L., Santos-Reis M., 2002. Feeding habits of the common genet *Genetta genetta* (Carnivora: Viverridae) in a semi-natural landscape of central Portugal. *Mammalia*. 66, 2: 195–206.

Rosalino L., Loureiro F., Macdonald D., Santos-Reis M., 2004. Dietary shifts of the badger *Meles meles* in Mediterranean woodlands: an opportunistic forager with seasonal specialisms. *Mammalian Biology* 70: 12–23.

Rosalino, L. M., Santos, M. J., Domingos, S., Rodrigues, M. & Santos-Reis, M., 2005. Estrutura populacional e dimensões corporais de carnívoros simpátricos num ecossistema Mediterrânico do Sudoeste Português. *Revista Biologia* (Lisboa). 23: 135-146.

Santos-Reis, M. 1983: Status and Distribution of the Portuguese Mustelids, *Acta Zoologica Fennica* 174: 213-216

Saunders D., Hobbs R. & Margules C., 1991. Biological consequences of ecosystem fragmentation: a review. *Conservation Biology* 5: 18-32.

Schwanz, L., 2000. "*Martes martes*" (On-line), Animal Diversity Web. Accessed April 07, 2011 ([http://animaldiversity.ummz.umich.edu/site/accounts/information/Martes\\_martes.html](http://animaldiversity.ummz.umich.edu/site/accounts/information/Martes_martes.html))

Sidorovich V., Krasko, D., Dyman, A., 2005. Landscape-related differences in diet, food supply and distribution of the pine marten, *Martes martes* in the transitional mixed forest of northern Belarus, The Vertebrate Predation Research Group, Institute of Zoology, National Academy of Sciences of Belarus. *Folia Zoologica*. 54, 39–52.

Smith, A.C., Schaefer, J.A., 2002. Home-range size and habitat selection by American marten (*Martes americana*) in Labrador, *Canadian Journal of Zoology*, 80: 1602-1609.

Storch I., Lindstrom E., de Joune J., 1990. Diet and habitat selection of the pine marten in relation to competition with the red fox. *Acta Theriologica*, 35: 311-320.

Teddlie, C., Yu, F., 2007. Mixed methods sampling: A typology with examples. *Journal of Mixed Methods Research*, 1: 77-100.

Trzcinski M., Fahrig, L., Merriam, G., 1999. Independent Effects of Forest Cover and Fragmentation on the Distribution of Forest Breeding Birds. *Ecological Applications*, 9: 586-593.

Velander, K. A., 1983. Pine marten survey of Scotland, England and Wales 1980–1982. The Vincent Wildlife Trust, London, UK.

Velander, K., 1991. Pine marten, *Martes martes*. In: Corbet, G.B. & Harris, S. (Eds.) The Handbook of British Mammals. Blackwell Scientific Publications, Oxford.

Wilcove, D.S., Rothstein, D., Dubow, J., Phillips, A., Losos E. 1998. Quantifying threats to imperiled species in the United States. *BioScience* 48: 607-615.

Wilcox, B., Murphy, D., 1985. Conservation strategy: the effects of fragmentation on extinction. *American Naturalist*. 125: 879-887.

Wund, M., Myers P., 2005. "Mammalia" (On-line), Animal Diversity Web. Accessed April 05, 2011, University of Michigan, Museum of Zoology (<http://animaldiversity.ummz.umich.edu/site/accounts/information/Mammalia.html>).

Zalewski, A., Jedrzejewski W., Jedrzejewska B., 1995. Pine marten home ranges, numbers and predation on vertebrates in a deciduous forest (Bialowieza National Park, Poland). *Annales Zoologici Fennici*, 32: 131-144.

Zalewski, A., 1997. Factors affecting selection of resting site type by pine marten in primeval deciduous forests (Bialowieza National Park, Poland). *Acta Theriologica*, 42: 271-288.

Zalewski, A., 2004. Geographical and seasonal variation in food habits and prey size of European pine martens. in: D.J. Harrison, A.K. Fuller, & G. Proulx (eds.) *Martens and Fishers (Martes) in Human-altered Environments*. Springer, London, UK. 77-98.