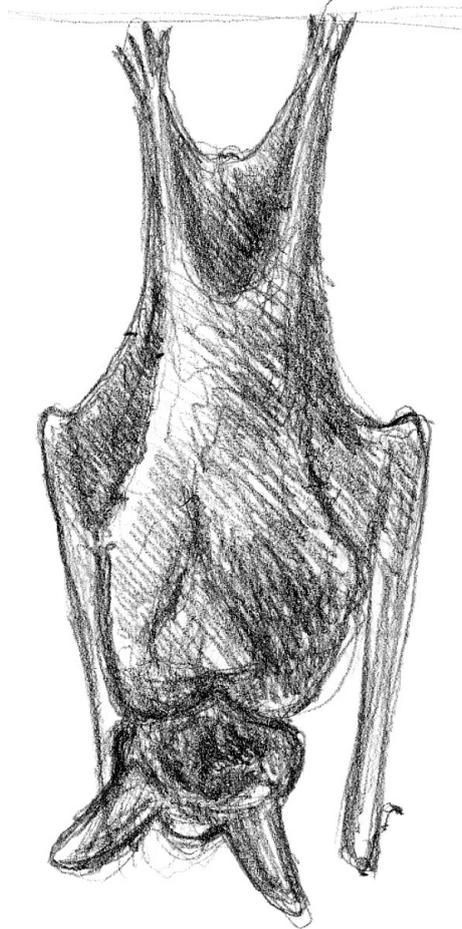


How modern agriculture reduces the overall ecological space :

comparison of mouse-eared bats' niche breadth in  
intensively vs. extensively cultivated areas

*Myotis myotis* (Borkhausen, 1797), *Myotis blythii* (Tomes, 1857)



Master thesis  
by

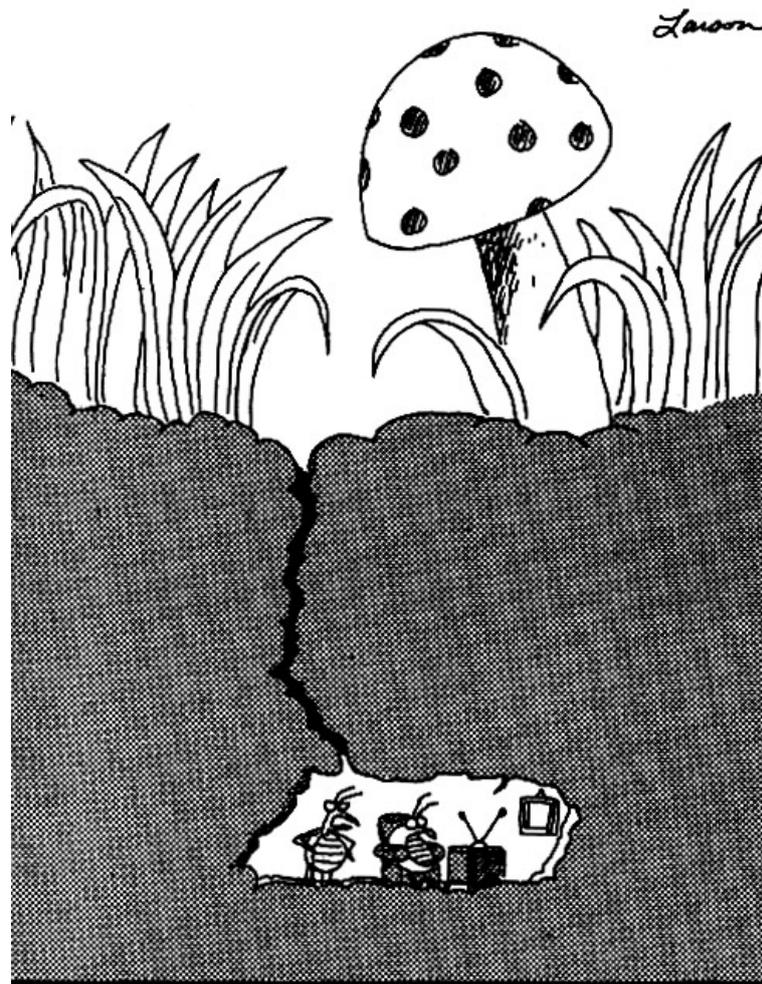
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2004

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**“You call this a niche?”**

## **Keywords**

Chiroptera; *Myotis myotis*; *Myotis blythii*; radiotracking; Lower Valais; Upper Valais; ecological niche; intensive farming system; habitat loss; habitat diversity; population density; Ecological Niche Factor Analysis, habitat suitability model.

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## Summary

1. Bats are all considered as endangered species in Switzerland. The causes of removal of bats are numerous. Roost removal, disturbance at roost and predation have a direct and well known impact on bat populations and are minimized by the work of the Swiss Bat Conservation Groups. In contrast, the impact of landscape removal, habitat loss and intensification of the agriculture are more difficult to correct. This study compares the niche of two sibling bat species (*Myotis myotis* and *Myotis blythii*) in intensively vs. extensively cultivated farmland. A declining bat population (Lower Valais, SW Switzerland) inhabits an intensive farming system (nearly 20 individuals of both species), whereas another population in Upper Valais inhabits an extensive farming system (400 individuals of both species). The study was divided in two parts. First bat foraging, habitat diversity and bat population densities were estimated in the two areas. Then the niches were modelled with the Ecological Niche Factor Analysis (ENFA); we also computed Habitat Suitability maps with topographical, ecological and human variables. A Landsat-5TM imagery was used to compute a vegetation index (NDVI).
2. Habitat diversity : data on foraging areas were collected by radiotracking in 1989-1993 and in 2003. Foraging habitat diversity was quantified with the Levins' B index for area and species separately. It was found to be significantly higher in Upper Valais ( $B = 3,57$ ) than in Lower Valais ( $B = 1,62$ ) only for *M. myotis*, as the sample size for *M. blythii* was too low in Lower Valais ( $B = 2,33$  in Lower Valais and  $B = 3,06$  in Upper Valais). The two species used more habitat types in Upper Valais than in Lower Valais : 21 different habitats were visited by *M. myotis* in Upper Valais vs. 14 in Lower Valais. *M. blythii* visited 18 types of habitat in Upper Valais and 14 in Lower Valais. The bat population density also showed an important difference between Upper and Lower Valais. A population of 21 bats (Jolly-Seber model) occupies a foraging area of 138 km<sup>2</sup> (Minimum Convex Polygon : 0,16 bats per km<sup>2</sup>) in Lower Valais, whereas a population of 390 bats forages on an area of 189 km<sup>2</sup> (Minimum Convex Polygon : 2,07 bats per km<sup>2</sup>). There is thus a difference in habitat suitability between the two areas.

- 3.** ENFA and Habitat Suitability maps : different niches are occupied by the two species in Upper and Lower Valais. In Lower Valais, *M. myotis*' suitable habitat consists mainly of orchards. In Upper Valais, meadows, pastures and forests are the most suitable habitats. For *M. blythii*, suitable habitat in Lower Valais is composed by bushy forests, bushes and unproductive vegetation on slopy areas. In comparison, in Upper Valais, *M. blythii* has suitable habitats in areas with meadows, bushes and open forest. For both species the values of marginality and tolerance show differences between Lower and Upper Valais. There is a narrower niche for Lower Valais with a lower tolerance to deviation from optimal habitats for *M. myotis* as for *M. blythii*.
- 4.** Conclusion : we can conclude to an effect on *M. myotis* and *M. blythii* by the intensive farming system and by the urbanism occurring in Lower Valais. The Lower Valais population is small and vulnerable to further fragmentation of its habitat. Orchards, steppe and meadows must be preserved within a range of 10 kilometers of the Lower Valais' colony and extensive farming system must also be favoured in Upper Valais.

## Résumé

1. La majorité des espèces de Chiroptères sont considérées comme menacées. Les causes de déclin des populations sont nombreuses. La destruction et le dérangement des colonies ainsi que la prédation sont des problèmes connus et leur impact peut être limité par le travail des Centres de Coordination pour l'étude et la protection des chauves-souris. Le morcellement de l'habitat, sa disparition et l'intensification de l'agriculture sont des facteurs plus difficiles à gérer. Cette étude présente une comparaison entre deux systèmes agricoles par l'utilisation des niches écologiques de deux espèces jumelles de murins, *Myotis myotis* et *Myotis blythii*. Une population en déclin (une vingtaine d'individus) vit dans le Bas-Valais (S-O de la Suisse) dont l'agriculture est principalement intensive et une autre population (presque 400 individus) vit dans le Haut-Valais, région exploitée encore extensivement, les deux populations se situant à une distance de 100 km l'une de l'autre. Cette étude comporte deux parties. Dans un premier temps, la diversité d'habitats, la fréquence des habitats visités et une estimation de la densité de la population de *M. myotis* et *M. blythii* ont été analysées pour comparer les deux zones d'étude. Ensuite l'habitat a été modélisée par l'analyse factorielle de la niche écologique (ENFA) et par des cartes d'habitat potentiel avec des variables topographiques, écologiques et anthropiques. Une image Landsat-5TM a également été utilisée pour calculer un indice de végétation (NDVI).
2. Diversité d'habitat : les données de terrains de chasse de *M. myotis* et *M. blythii* ont été récoltées par radiopistage entre 1989-1993 et en 2003. La diversité d'habitats a été quantifiée par l'index B de Levins pour chaque zone d'étude (Haut-Valais et Bas-Valais) et pour chacune des deux espèces de murin. *M. myotis* utilise significativement plus d'habitats en Haut-Valais ( $B = 3,57$ ) qu'en Bas-Valais ( $B = 1,62$ ) alors que la différence pour *M. blythii* n'est pas significative, cela étant dû à un échantillonnage incomplet ( $B = 2,33$  en Bas-Valais et  $B = 3,06$  en Haut-Valais). La fréquence d'habitats visités montre que les deux espèces utilisent plus d'habitats différents en Haut-Valais qu'en Bas-Valais. *M. myotis* a visité 21 habitats différents en Haut Valais et seulement 14 dans le Bas-Valais. *M. blythii* a visité 18 habitats en Haut-Valais et 14 dans le bas du canton. La densité de population de murins montre également des différences importantes entre le Haut-Valais et le Bas-Valais. Une population de 21 murins (*M. myotis* et *M. blythii*, estimation basée sur le modèle de Jolly-Seber) a ses terrains de chasse, dans le Bas-Valais, sur une surface de 138 km<sup>2</sup> (polygone convexe minimum : 0,16 murin par km<sup>2</sup>) alors qu'une population de 390 murins (*M. myotis* et *M. blythii*) a ses terrains de chasse en Haut-Valais sur une surface de 189 km<sup>2</sup> (polygone convexe minimum, 2,07 murins par km<sup>2</sup>). Il y a donc une différence dans la diversité d'habitats à disposition des murins entre le Haut-Valais et le Bas-Valais.

- 3.** ENFA et cartes d'habitat potentiel : différentes niches sont occupées par les deux espèces si l'on considère la population haut valaisanne ou la population bas-valaisanne. D'après les résultats de l'ENFA, en Bas-Valais et pour *M. myotis*, l'habitat favorable sera principalement constitué de vergers alors qu'en Haut-Valais ce sont les prairies, les pâturages et les forêts qui constituent les habitats les plus favorables. Pour *M. blythii*, les habitats sont constitués de forêt buissonnante, de zones broussailleuses et de végétation improductive sur des zones pentues. Au contraire, en Haut-Valais, *M. blythii* a des habitats favorables dans des zones de prairie, des zones broussailleuses et dans les forêts clairsemées. Pour les deux espèces, les valeurs de marginalité et de tolérance montrent des différences entre le Bas-Valais et le Haut-Valais. Il y a une niche plus étroite pour la population bas-valaisanne avec une tolérance très faible envers une variance de son habitat optimal.
  
- 4.** Conclusion : on peut conclure que l'agriculture intensive et l'urbanisation ont un effet négatif sur *M. myotis* et sur *M. blythii* vivant dans le Bas-Valais. La population bas-valaisanne est faible et sensible face à un plus grand fractionnement de son habitat. Les vergers, steppes et prairies restantes devraient être maintenus dans un rayon de 10 km de la colonie et l'agriculture extensive devrait être favorisée dans le Haut-Valais.



## 1. Introduction

Recently, several major scientific journals have addressed the problem of the growing human impact on biodiversity. As hunting and fishing were already known to have an important impact on wildlife (Whitfield 2003), climate change and population growth seem to have other important effects on biodiversity (Cohen 2003; Jenkins 2003; Pounds & Puschendorf 2004; Thomas et al. 2004). At local scale Human activity induces the fragmentation and the loss of habitat by the growth of the cities and the more and more important need of arable land for intensive farming systems (Andr n 1994; Jenkins 2003). But as revealed by Villard (2002), fragmentation is difficult to translate into management rules because any habitat fragmentation is a special case, related to the local conditions and to the local wildlife populations. Generalisation is thus difficult in such studies. Several authors addressed this problem in theory, but only a few were able to make links between theory and practice (Andr n 1994; Hehl-Lange 2001; Schadt et al. 2002; Kristan 2003; Naves et al. 2003). The habitat suitability models are then an interesting tool for linking theory to reality of wildlife removal. This allows to show unexpected relations between variables and species and enables us to develop conservation or reintroduction policy (Jaberg & Guisan 2001; Schadt et al. 2002; Hirzel et al. 2002a; Naves et al. 2003; Hirzel et al. submitted). For these studies, indicator or emblematic species, such as Lynx, Bear, birds, etc., are chosen to construct the models because they are representative of a specific environment. Birds are also often used as a few breeding seasons can be enough for a study on the effect of habitat fragmentation (Andr n 1994; Bender et al. 1998). Bats are good indicators of general habitat quality regarding both disturbance and the existence of contamination (Hartmann 2002; Fenton 2003). As insectivores, they represent one of the upper levels of the food chain, and are therefore sensitive to any alteration of their environment. Several surveys occurred in European countries such as England (Walsh & Harris 1996 a,b.), Ireland (Russ & Montgomery 2002), the Netherlands (Limpens & kapteyn 1991), Scandinavia (de Jong 1995), and all concluded to the importance of the maintenance of landscape structures (mainly the linear landscape elements). Other studies revealed the bat's habitat selection and the importance of insect abundance for the bats' survival (Sierro 1999; G ttinger 1997; Jaberg et al. 1998; G ttinger et al. 1998; Arlettaz 1995; Bontadina et al. 2002a; Russo et al. 2002). It is important to consider that most of our landscape is constructed by human farming systems. Pastures, meadows and traditional orchards are considered as low-intensity farming systems and are abandoned for more intensive practices (Bignal & McCracken 1996; Office F d ral de la Statistique 2002 a,b; Jenkins 2003). Bats feed mainly in our agricultural environment but they are directly dependent on the landscape fragmentation, habitat loss and intensification of the farming system (e.g. pesticides, lower prey availability), Walsh & Harris (1996b) also found a decline in bat abundance from North Wales to the East coast of England. They explained this decrease by the intensive agriculture policy of the eastern part of England. A recent paper also addressed the problem of habitat used by bats on intensive landscape (Wickramasinghe et al. 2003). In Switzerland there are all the conditions to work on the effect of loss of habitat diversity and on bat population decline.

We worked on the sibling species of mouse-eared bats (*Myotis myotis*, Borkhausen 1797, and *Myotis blythii*, Tomes, 1857). *M. blythii* lives only in mixed colonies with *M. myotis*. All those mixed colonies are more or less situated in the southern part of Switzerland : one colony in Tessin, five in the Rhine valley and three in the Rhône Valley (data from the Eastern and Western Centre of the Swiss Bat Conservation, in Zürich and in Geneva). *M. myotis* is distributed throughout Switzerland, with almost one hundred roosts (Office Fédéral de l'Environnement des Forêts et du Paysage 1994; Hausser 1995; Güttinger 1997; Güttinger pers. comm.) and *M. blythii* is a vulnerable species in Switzerland (Office Fédéral de l'Environnement des Forêts et du Paysage 1994). The sibling species have been well studied in Switzerland (Arlettaz 1995; Güttinger 1997; Güttinger et al. 1998). *M. myotis* forages in agricultural landscape (meadows, orchards and forests) (Arlettaz 1995; Güttinger 1997) whereas *M. blythii* is more demanding and forages in steppes or in wet meadows (Arlettaz 1995; Güttinger et al. 1998). The Rhône valley is divided in two important landscapes. An intensive farming system occurs in Lower Valais and an extensive farming system occurs in Upper Valais. In this area there are three known mixed colonies creating two separate populations, one, declining, located in Lower Valais (in Fully), and the other in Upper Valais (in Raron and Naters). The two populations in the Rhône valley are 100 km away from each other. It is far enough not to have any exchange of individuals between the two populations and close enough to compare the intraspecific niches.

For this master thesis I aimed to compare the habitat diversity between the intensive farming system of the Lower Valais and the extensive farming system of the Upper Valais. Data used for this comparison is partly Arlettaz' data (1999) and further radiotracking studies were done during the summer 2003 to complete the data. The habitat diversity analyses were completed by the computation of the Ecological Niche Factor Analysis (ENFA) and of habitat suitability maps (Hirzel 2002a) to try to understand the causes of the decline of the colony in Lower Valais.

## 2. Material and Methods

### 2.1. Radiotracking study

Radiotracking took place in the Rhône valley, canton of Valais, SW Switzerland, on the three roosts of the sibling species *Myotis myotis* (Borkhausen, 1797) and *Myotis blythii* (Tomes, 1857) in Fully (N46°08' E7°06'), Raron (N46°18' E7°47') and Naters (N46°19' E7°59'). The data were collected in two sessions. The first one by R. Arlettaz between 1989 and 1993 (10 *M. myotis* and 10 *M. blythii*, Arlettaz 1999) and the second during this master thesis (4 *M. myotis* and 2 *M. blythii*). Habitat selection was investigated in Fully, Lower Valais, from 19th June to 22nd September 2003. Ten bats were radio-tracked during this period, five *M. myotis* and five *M. blythii*. I eliminated four bats from the analyses (3 *M. blythii* and 1 *M. myotis*) due to the destruction or the loss of the transmitters. Sample size for the Valais is 14 *Myotis myotis* (7 in Upper Valais and 7 in Lower Valais) and 12 *Myotis blythii* (7 in Upper Valais and 5 in Lower Valais). Bats were fitted with transmitters (BD-2P, 1-1,3 g, Holohil systems, Ontario, Canada) fixed on their back between the shoulders with a surgical adhesive (Skin-Bond, Smith and nephew United Inc, Largo, Florida USA) with a piece of reflector tape glued on the transmitter. This allowed me to identify the marked bat in the field by visual observation, as there was often two or three *Myotis* bats foraging in the same area (personal observation). Bats were captured at the colony from 19th June to 13th August and in a cavity (Poteux) from 17th August until 22nd September. The exceptional weather conditions of the summer 2003 caused the departure of all bats two weeks earlier than usual (early August). The transmitters were recovered at the roost at night after they fell down from the back of the mouse-eared bats.

Radiotracking took place between dusk and dawn without interruption. Bats were followed by car until they reached their foraging area. I then searched on foot, by “homing in on the animal“ (White & Garrot 1990). I used a receiver (Yaesu FT-290R2, Karl Wagner, D-5000 Köln 1, Germany) and a H-antenna when radiotracking on foot and an omnidirectional antenna when searching bats by car. Six kinds of activities were recorded in the field : (i) resting at the day roost, (ii) night resting in the foraging area, (iii) commuting flight, (iv) foraging activity, (v) unidentified activity, (vi) observer's failure. At the same time an estimation of the location of the bat was done with six classes of accuracy : (a) visual observation, (b)  $\pm 20$  m, (c)  $\pm 50$  m, (d)  $\pm 100$  m, (e)  $\pm 200$  m, (f)  $> 500$  m. The best accuracy being the visual observation with a night scope (Leica Big25, Leica Geosystem AG, 9435 Heerbrugg, Switzerland) and a torch. The foraging areas were divided into 1-ha cell units according to the official grid of the Swiss Federal Topographic Service. Each cell visited by bats was associated with a category of habitat chosen from a list of 31 habitat types (Arlettaz 1999) (Table 1). The dominant habitat type inside the cell was used and recorded directly in the

field, with the activity and accuracy classes. Foraging areas were defined by Arlettaz (1999) as a group of 5 1-ha contiguous cells visited by mouse-eared bats. Two apparent foraging areas had to be eight hundred meters far away from each other to be considered as distinct foraging areas. All contacts with bats (sound and/or visual contact) were recorded on a dictaphone and written on a computer in a full text format on the following day.

Radiotracking data (activity, accuracy, habitat and XY coordinates) were recorded in a database created by R. Arlettaz for all *Myotis myotis/blythii* radiotracked since 1989, and the capture data were recorded in the database of the Bat Conservation group of Valais. The field work was done under license from the Nature Conservation Service of the State of Valais.

## 2.2. Habitat diversity

### 2.2.1. Levins index

The main comparison of the two areas was performed on the basis of habitat diversity. This diversity is given by the Levin's B index (Krebs 1989) already used for bats by Arlettaz et al. (1997a), Arlettaz (1999) and Bontadina (2002a) :

$$B = 1/\sum p_i^2$$

B= Levin's measure of habitat breadth

$p_i$ = proportion of habitat of category i

This index ranges from 0 to n, n being the total number of habitat types, which is 31 in our study (Table 1). This index is calculated for each individual. All the 1-Ha cells visited by each mouse-eared bat (foraging activity (iv) with an accuracy smaller than 50 m) were used for the calculation of the indices. Comparison of the indices between Lower and Upper Valais was tested with a 1-tailed Mann-Whitney U-test. A total of 830 1-ha cells, 429 for *M. myotis* and 401 for *M. blythii* were used for the calculations.

TABLE 1 : List of categories of habitat used by Arlettaz (1999). The relation to the vegetation classification is indicative of the landscape in Valais. Calcicole and Silicious are the two main geological requirements for the plants (Delarze et al. 1998).

Habitat categories	Habitat type	Indicative vegetation group calcirole	Indicative vegetation group silicious	Dominant tree species	
I Rocky	1.1 Cliff	<i>Potentilla</i>	<i>Androsacis vandellii</i>		
	1.2 Stony outcrop	<i>Alyso-Sedion</i>	<i>Sedo-Veronicion</i>		
	1.3 Scree	<i>Stipion calamagrostis</i>	<i>Galeopsision segetum</i>		
	1.4 Urbanised	<i>Saginion procumbentis</i>			
	1.5 Open fields	<i>Panico-Setarion</i>			
	1.6 Vineyard	<i>Fumario-Euphorbion</i>			
IV Water	2.1 Fresh water	-	-		
	V Steppe	3.1 Steppe on stony outcrop or scree	<i>Alyso-Sedion</i>	<i>Sedo-Vernicion</i>	
		3.2 Open steppe (<50% bushes)	<i>Stipo-Poion</i>		
		3.3 Bushy steppe (>50% bushes)	<i>Berberidion</i>		<i>Quercus pubescens</i>
VI Pasture	3.4 Wooded steppe (<50% trees)	<i>Ononido-Pinton</i>		<i>Quercus pubescens</i> , <i>Betula pendula</i> , <i>Larix decidua</i> , <i>Pinus sylvestris</i>	
	4.1 Steppic pasture	<i>Cyrcio-brachypodion</i> or <i>Stipo-Poion</i>			
VII Dense meadow	4.2 Xeric pasture or abandoned meadow	<i>Convulvulo-Agropyrion</i>			
	4.3 Wet pasture	<i>Caricion ferrugineae</i>			
	5.2 Meagre meadow	<i>Xerobromion</i>			
	5.4 Mesophilous meadow	<i>Mesobromion</i>			
VIII Mown meadow	5.1 Meagre meadow	<i>Xerobromion</i>			
	5.3 Mesophilous meadow	<i>Mesobromion</i>			
	7.1 Traditional orchard	-		Apple	
IX Orchard	7.2 Traditional orchard	-		Apricot	
	7.3 Intensively cultivated orchard	-			
	X Deciduous forest (>50% deciduous)	8.1 Xerothermic forest (oaks)	<i>Quercion pubescenti-petraeae</i>		<i>Quercus pubescens</i>
8.2 Xerothermic forest (other)		<i>Cephalanthero-Fagenion</i>		<i>Sorbus aria</i> , <i>Fraxinus excelsior</i> , etc.	
8.3 Chestnut forest		-		<i>Castanea sativa</i>	
8.4 Riparian forest		<i>Salicion albae</i>		<i>Populus alba</i> , <i>P. nigra</i> , <i>Salix sp.</i>	
X Mixed forest	9.1 Xerophilous forest	<i>Abieti-Fagenion</i>		<i>Fagus sylvatica</i> , <i>Picea abies</i> , <i>Abies alba</i>	
	9.2 Xerophilous forest	-		<i>Larix decidua</i> , <i>Picea abies</i> , <i>Betula pendula</i> , <i>Sorbus aria</i> , <i>Castanea sativa</i> , <i>Pinus sylvestris</i>	
X Coniferous forest (>50% coniferous)	10.1 Pine forest	<i>Erico-Pinion</i>		<i>Pinus sylvestris</i>	
	10.2 Spruce forest	<i>Vaccinio-Piceion</i>		<i>Picea abies</i>	
	10.3 Larch forest	<i>Mélezein</i>		<i>Larix decidua</i>	
	10.4 Mixed coniferous forest	-		<i>Larix decidua</i> , <i>Picea abies</i> , <i>Abies alba</i> , <i>Pinus sylvestris</i>	

### 2.2.2. Foraging habitat frequency

With the diversity I wanted to investigate the total number of the habitats visited by the bats in each area. I used the 31 habitat categories (Table 1) and counted the number of visited cells of a given category, per species. The frequency and percentage of each category and the total number of habitat types used by bats were calculated. Data came from the radiotracking database (foraging activity (iv) and accuracy smaller than 50 m). The difference between the two areas was not tested. The Levins index gives an idea of the diversity, which is related to the amount of habitat used.

### 2.3. Population density

As a complement of the habitat diversity study, an estimation of the density of mouse-eared bat was done in the two areas. The density was calculated as a function of population size divided by the area used by the whole colony, this area being estimated from radiotracking data.

$$D = N_i/S_i$$

D = density of bats per km<sup>2</sup>

N<sub>i</sub> = population size of the colony i

S<sub>i</sub> = surface used by the colony i in km<sup>2</sup> (Minimum Convex polygon)

N<sub>i</sub> and S<sub>i</sub> were both calculated separately on the basis of the method described in the following sections (§2.3.1. Population size and §2.3.2. Area).

#### 2.3.1. Population size

The population size was estimated through the Jolly-Seber model using MARK software. This model gives an estimation of the population during a capture-recapture (CR) experiment (Pollock et al. 1990; Anderson & Burnham 1999a). The data of CR are in the database of the Bat Conservation group of Valais as several CR sessions occurred every years since 1986. Young bats and unmarked adult bats were ringed and ringed adults were controlled. I consider several captures of the same bat during one year as one capture event, which allows to have a comparable capture probability from one year to another. This eliminates one of the major bias in CR experiments which is the permanent trap response. It refers to a situation in which the change in capture probability with initial capture persists for the remainder of the CR experiment which

actually occurs with bat CR experiments (Pollock et al. 1990). The choice of the right period of CR faces some constraints, the main being that CR sessions must occur each year. If no capture is made one year, the population size will be biased. No capture were done in 1994 in the three roosts and in 2001 in Fully. This gives a period between 1995 and 2000 used as reference basis. I did not use the previous years (from 1986 to 1994) because I wanted to have the most recent population estimation as possible. The year 2000 was removed from the analysis because only young bats were controlled in Fully and I used data of adult females for the estimation, as the population size is based only on the females (Schoeber & Grimmeberg 1991). And finally open population models require at least 3 sampling periods (Pollock et al. 1990). I ran model with *M. myotis* and *M. blythii* separately. Only the data from Fully are used for the Lower Valais and the data of both Raron and Naters pooled together are used for the Upper Valais. We can consider those two colonies as a single population as there are exchanges between the two roosts. Bats ringed in Raron were captured the following years in Naters, and vice versa.

The Jolly–Seber model use four different parameters, survival probability ( $\phi$ ), capture probability ( $p$ ), population growth rate ( $\lambda$ ) and population size ( $N$ ). The models are based either on : constant parameters across groups and time ( $\cdot$ ), group-specific parameters but constant with time ( $g$ ), time-specific parameters constant across group ( $t$ ) and parameters varying with both group and time ( $g \times t$ ). In the analysis the capture probability must be time dependent ( $p(t)$ ), because the capture effort is not regular every year. If there is a strong variation of this parameter the model fails. I tested the capture rate with the Cormack-Jolly-Seber model with a  $\phi(\cdot)p(t)$  model. The most constant capture rate occurred during the years 1997 to 1999. I ran several models with the parameters constant, time-dependent and / or group dependent. I used the default SIN function because it is the more efficient for parameters estimation (White & Burnham 1999). The best model is chosen on the basis of the Akaike's information criterion (AICc) given by the QAIC in MARK, which is a modified criterion of the AICc (White & Burnham 1999; Lebreton et al. 1992; Naves et al. 2003). The model with the smallest QAIC is estimated to be a reasonable model for a particular dataset (Anderson & Burnham 1999b; Lebreton et al. 1992). With all models a model average was calculated by MARK for each group. This recalculates an estimate on the basis of the AICc weight of the model with all the models of the result file. This is a better approximation of the population for both species.

### 2.3.2. Area

The area was estimated on the basis of the home range of the entire colony for each zone. It is calculated with the radiotracking data with a foraging activity (iv) and an accuracy smaller than 50 m for both *M. myotis* and *M. blythii*. I used the Minimum Convex Polygon (MCP), which is the oldest and the easiest home range method to calculate but that contains several bias (White & Garrot 1990). Several authors consider that only one method is not enough for estimating the home range, the best compromise being a MCP with a Utilisation Distribution method such as Kernel estimation (Harris et al. 1990; Alldredge & Ratti 1992; Kernohan et al. 2001). We need an estimation of the general area used by the whole colony. Thus, only the MCP is used for the estimation of the colony home range. As with other home range estimators, the locations are assumed to be independent (White & Garrot 1990; Kernohan et al. 2001; Arlettaz 1999). MCP was calculated with the "Animal movement" extension (Hooge & Eichenlaub 1997) which compute several home range estimators in the GIS software Arc View 3.2 (ESRI 1992-1999).

## 2.4. Ecological Niche Factor Analysis (ENFA)

An ENFA was performed with the GIS software BIOMAPPER 2.1 (Hirzel et al. 2002b) which is the most adapted when only presence data are available (Hirzel et al. 2001). The ENFA needs ecogeographical variables (EGVs) describing the characteristics of each cell in the study area. The analysis compares the EGVs of the presence data-set to those of the whole study area. The correlated variables are then summarized in a few independent factors that contain the major part of the habitat information (Hirzel et al. 2002a). ENFA is based on the concept of ecological niche (Hutchinson 1957) that assumes that the occurrence of species is limited to a range within a multidimensional space. The cells form a cloud in the space defined by the environmental predictors, part of which contains cells where the species has been observed.

### 2.4.1. EGVs and study area

All the EGVs were prepared as raster maps (cell size = 1 ha) for the whole Valais. The Swiss Coordinates System was used for all maps as a reference grid. Arlettaz (1999) in his habitat selection analysis of mouse-eared bats showed that a few habitats are important for the bats such as mown and dense meadows, open forests, orchards, steppe, pastures. Governmental data (Geostat, Vector 200, Office Fédéral de la Statistique 1996) exist for most variables (Table 2), but GIS data does not exist for dynamic variables such as mown meadow (two to three cuts per year). We used a LANDSAT-5 TM image to compute a Normalized

Difference Vegetation Index (NDVI, Tucker 1979), indicating the presence of green active biomass. The topographical variables (aspect, elevation, slope) were already quantitative. Other variables, such as land use and anthropogenic data were boolean and had to be made quantitative using the module CircAn of BIOMAPPER 2.1. This module calculates the frequency of occurrence of the variable within a given radius. This radius depends on the species space-use pattern. Bontadina (unpubl. data) conducted a radiotracking study with *M. blythii* in Tessin (Switzerland) and tested models with different radius (from 1,2 km to 500 m). He found that frequency calculated with a small radius gave a better model for mouse-eared bats. I therefore chose a radius of 500 m for both species, which corresponds to 5 1-ha cells in Biomapper. The distribution of the EGVs were also normalized by the Box-Cox algorithm (Sokal & Rolf 1994). I did not use the same variables for the two species as the choice of EGVs is mainly based on the habitat selection analyses conducted by Arlettaz (1999). Thus orchards and forests were not used for *M. blythii* as this species does not forage in these areas. Bushy forest was also not used for *M. myotis* as this kind of forest is too dense for this species. It was used for *M. blythii* because this forest is mainly around the steppe where it forages. Two variables had to be removed during the analyses because they were too much correlated. In such case of high correlation in a set of variable, all but one of these variable are removed from each highly correlated set (Erickson & West 2002). Thus the variable "mayen" (typical Swiss word for the alpine chalet) was removed from the analyses of *M. myotis* and the variable "pasture" was removed from the *M. blythii* analyses. Eighteen EGVs were used for *M. myotis* analyses and seventeen EGVs were used for *M. blythii* analyses (Table 2).

TABLE 2 : List of all ecogeographical variables (EGV) used for ENFA analyses. Topographical and Landsat variables were already quantitative. Human and Ecological boolean variables were transformed (frequency) to be quantitative. Not all variables were used for both species.

EGV	Type of variable	Map quality	<i>M. myotis</i>	<i>M. blythii</i>
Elevation	Topographical	quantitative	X	X
Slopes	Topographical	quantitative	X	X
Eastness	Topographical	quantitative	X	X
Northness	Topographical	quantitative	X	X
Buildings	Human	frequency	X	X
Roads	Human	frequency	X	X
Vineyard	Human	frequency	X	X
NDVI	Landsat-5TM	quantitative	X	X
Landsat - PCA1	Landsat-5TM	quantitative	X	X
Landsat - PCA2	Landsat-5TM	quantitative	X	X
Landsat - PCA3	Landsat-5TM	quantitative	X	X
Orchard	Ecological	frequency	X	
Bushy forest	Ecological	frequency		X
Open forest	Ecological	frequency	X	X
Dense forest	Ecological	frequency	X	
Mayen	Ecological	frequency		X
Meadow	Ecological	frequency	X	X
Pasture	Ecological	frequency	X	
Unproductive vegetation	Ecological	frequency	X	X
Bushes	Ecological	frequency	X	X

### 2.4.2. LANDSAT-5 Thematic Map

To improve the model we chose to use a LANDSAT-5 TM image (reference grid 195-28, taken the 31.8.1998, Satellite Image © ESA / Eurimage / Swisstopo, NPOC) to classify vegetation. Remote sensing data are frequently used to analyse the vegetation evolution (Su 2000; Waser et al. 2003; Bauer et al. in press) on the basis of several vegetation indices developed in the late 80's (Tucker 1979). Those indices are computed with the reflectance of the 6 different bands (Appendix 1). I finally chose the Normalized Difference Vegetation Index (NDVI, Tucker 1979) which is the most commonly used (Su 2000).

$$NDVI = (R_{nir} - R_{red}) / (R_{nir} + R_{red})$$

$R_{nir}$  = near infrared reflectance obtained from remote sensing data (Band 4, 0,76-0,90  $\mu\text{m}$ )

$R_{red}$  = red reflectance (Band 3, 0,63-0,69  $\mu\text{m}$ )

In addition to this index, I used the information of the 6 different bands furnished by the Landsat imagery (Appendix 1) and I ran a Principal Component Analysis (PCA) between the 6 bands in the GIS software Idris 32 (Eastmann 2002). The 3 first factors were chosen and they explained 98,97 % of the information. Instead of the six correlated bands, I therefore used only three uncorrelated maps based on these factors. The first map, which corresponds to the first factor of the PCA (Landsat – PCA1), is correlated to the monochromatic reflectance. The higher the reflectance of the pixel, in all wavelength, The higher its value on the first factor. This factor eliminates some misleading information, like shady or sunny areas so the following factors will have more discriminant power. The second factor (Landsat – PCA2) is correlated to the thermic (infrared) reflectance and the last factor (Landsat – PCA3) used is mainly correlated to the 4th and 6th bands. this last map is more or less insensitive to the other layers. Steppic area is not well defined in the geostat data. The images (Landsat-PCA1 and Landsat-PCA2) also differentiate the sunny south-facing slope from the shady north-facing slope, and thus should be a good ecogeographical variable for the steppic areas where *M. blythii* forage.

### 2.4.3. Species map

Habitat mapping was based on radiotracking data focusing on foraging activity (iv) with an accuracy smaller than 50 m. *M. myotis* and *M. blythii* have different specific ecological requirements (Audet 1990; Arlettaz et al. 1997a; Arlettaz 1999; Güttinger 1997; Güttinger et al. 1998; Drescher 2000), so I separated the species and ran separate ENFA analyses. In addition to the separation of the species, I computed three different boolean maps per species (presence / absence maps). Landscape use is basically different between Upper and Lower Valais and we could not consider only one model for the entire canton. Radiotracking data

from both Upper and Lower Valais were first used for a general model (Valais, map A for *M. myotis* and map D for *M. blythii*). The other species map were computed with data of Lower Valais (map B for *M. myotis* and map E for *M. blythii*) and Upper Valais (map C for *M. myotis* and map F for *M. blythii*), respectively. I used those two species maps (Lower Valais and Upper Valais species maps) to model the niche of mouse-eared bats for the whole Valais.

#### 2.4.4. Computation

Species are expected to be non-randomly distributed regarding ecological factors. In ENFA, variables of the cells with presence data are compared to the values of the other cells in such a way that calculation occurs in a multivariate way until all information is extracted. All factors bear an ecological meaning as in ENFA the first factor to be extracted is termed the "marginality factor", and the second factor is the first "specialization factor". The next is the second specialization factor, etc. There are as many factors as ecogeographical variables, but they are (i) uncorrelated and (ii) the major part of the information is embedded in the first factors. Marginality is a description of the particularity of the habitat and a species is expected to show some marginality as the species' mean differs from the global mean of all the variables. A marginality close to one means that the species lives in a particular habitat relative to the reference set. This value usually range between zero and one. Specialization factors provide information upon a species' dependence on a specific variable. A random set of cells gives a specialization of one, thus if the values are higher than one, then the species shows some specialization, it ranges between one and the infinite. The reciprocal of the specialization is the tolerance and varies between zero and one, with a value close to one indicating high tolerance towards deviation of the optimal habitat.

## 2.5. Habitat suitability maps

### 2.5.1. Computation

Habitat suitability (HS) maps are calculated on the basis of the factors extracted by the ENFA analyses. This number of independent factors to be included is selected with respect to Mac Arthur's broken stick distribution (Hirzel et al. 2002a). The suitability of any cell, that defines the quality of the habitat inhabited by a given species, is calculated from its situation relative to the species distribution on all selected factors. On one factor axis, calculation is based on a count of all cells from the species distribution that lay at least as far apart from the median value of the whole set of cells than from the focal cell (species distribution) (Fig. 1). This procedure is repeated a number of times corresponding to the number of factors included in the HS calculation. In order to account for the differential ecological importance of the factors, equal weights was attributed to marginality and specialization. But while all the marginality component goes to the first factor, the specialization component is apportioned among all factors proportionally to their eigenvalue (Hirzel et al. 2002a). In our case, every factor explaining 6% or more of the information was included in the HS calculation. For *M. myotis*, four factors were included in the HS calculation for the three species maps (map A-B-C) and for *M. blythii*, four factors were used for the Valais species map (map D) and the Lower Valais species map (map E); three factors were used for the Upper Valais species map (map F).

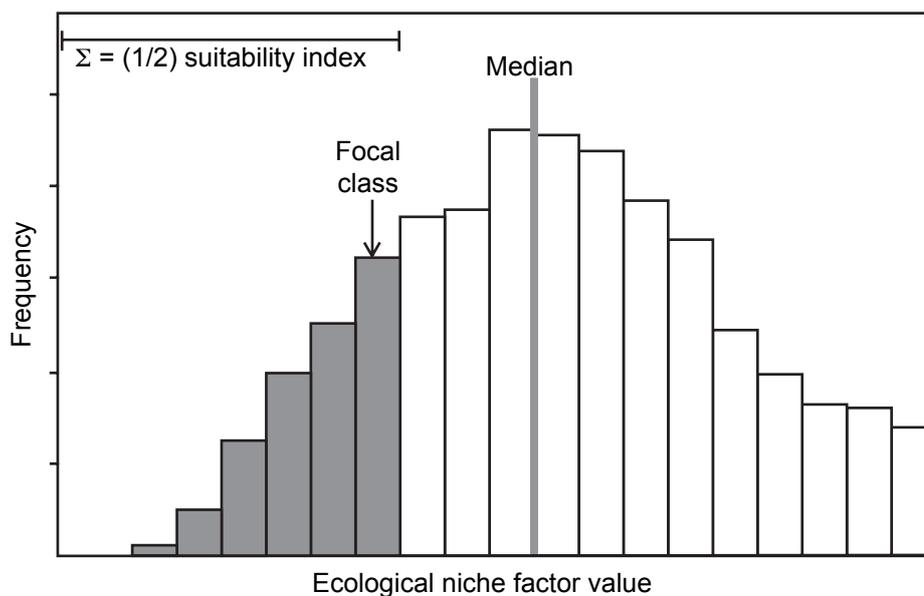


FIG. 1 : The suitability of any cell from the global distribution is calculated from its situation (arrow) relative to the species distribution (histogram) on all selected niche factors. Specifically, it is calculated as twice the dashed area (sum of all cells from the species distribution that lie as far or farther from the median dashed vertical line) divided by the total number of cells from the species distribution (surface of the histogram) (from hirzel et al. 2002a).

### 2.5.2. Model validation

The Jack-knife cross-validation (Fielding & Bell 1997) computes a confidence interval on the predictive accuracy of the habitat suitability (HS) model. The species locations are randomly partitioned into 100 mutually exclusive but identical-sized subsets. 99 partitions are used to calibrate a HS model and the left-out partition is used to evaluate it. This process is repeated ten times, each time by leaving out a different partition (Hirzel et al. 2003). Two indices demonstrating the accuracy of the distribution process are calculated : The Absolute Validation Index (AVI) and the Contrast Validation Index (CVI). The former (AVI) is the proportion of validation points occurring in the predicted core habitat. This indicates the fraction of validation cells (in the left-out partition) that have a HS value greater than 50. The latter (CVI) is the AVI minus the AVI that would have been obtained with a model predicting core habitat everywhere. It is indicating the fraction of cells that are greater than 50 with deduction of those cells that achieve this result by chance. This statistic gives an indication of how well the model discriminates highly suitable from lowly suitable habitat. This process is entirely performed within BIOMAPPER 2.1.

### 2.5.3. HS map comparison

As AVI / CVI is used to determine the best model, two more calculations were done for comparison of the different habitat suitability maps (HS maps). We expected that HS maps would be quite different if calculated with the Lower Valais data or with the Upper Valais data. To investigate this probable difference, a calculation was done in Idrisi 32. I subtracted the value of each pixel of the first map (Upper Valais species map) from the value of the same pixel of the other map (Lower Valais species map). This allows to visualize the main differences between the two HS maps. In addition to this subtraction, a mean habitat suitability value is calculated in a square by the GROUP STATISTICS module of BIOMAPPER 2.1 on the six habitat suitability maps. To increase the sample, the mean value was calculated on each of the ten HS maps created by each procedure of the Jack-knife cross-validation. To have a comparable surface for each colony, I used four different squares centered on the three roosts. The size of those squares was chosen on the basis of maximum and mean foraging distance of the mouse-eared bats (25 and 9 km for *M. myotis* and 10 and 4 km for *M. blythii*, Arlettaz 1999). Four squares were created, two per species, one for the maximum distance and the other for the mean distance. For *M. myotis* the two squares have a side-size of 50 km and 18 km, and for *M. blythii* the two squares have a side-size of 20 km and 8 km. I tested : (i) the difference of the mean habitat suitability values between the three species maps and (ii) the difference of the mean habitat suitability value between the three colonies. Statistical test consisted of a Kruskal-Wallis test for the two analyses.



## 3. Results

### 3.1. Radiotracking study

Bats carried transmitters during a total of 226 nights (8,7 nights per bat) and foraging activity was recorded during 117 nights (4,5 nights per bat), which is 51,8 % of the total number of nights (Table 3). A total of 830 1-ha cell units were used by bats for the foraging areas (30,6 1-ha cells per *M. myotis* and 33,4 1-ha cells per *M. blythii*, mean value). 43 foraging areas were found for the 26 bats (1,6 foraging area per bat, 25 foraging areas for *M. myotis* and 18 foraging areas for *M. blythii*). *M. myotis* foraged at a mean distance of 7,7 km (7,1 km in Lower Valais and 8,2 km in Upper Valais) and *M. blythii* foraged at a mean distance of 4,2 km (4,8 km in Lower Valais and 4,1 km in Upper Valais).

### 3.2. Habitat diversity

#### 3.2.1. Levins index

A difference in habitat diversity was found between the intensively vs. the traditionally cultivated area only for *M. myotis* (Lower Valais :  $B = 1,62 \pm 0,62$  and Upper Valais :  $B = 3,57 \pm 0,47$ , median  $\pm$  SD; Mann-Whitney 1-tailed U-test,  $p = 0,037$ ) but not for *M. blythii* (Lower Valais :  $B = 2,33 \pm 0,47$  and Upper Valais :  $B = 3,06 \pm 0,55$ , median  $\pm$  SD; Mann-Whitney 1-tailed U-test,  $p = 0,072$ ).

#### 3.2.2. Foraging habitat frequency

On the total of 31 habitat categories (Table 1), mouse-eared bats used more habitats in Upper Valais than in Lower Valais (Table 4). *M. myotis* used 14 different habitats in Lower Valais and 21 habitats in Upper Valais. *M. blythii* used 14 habitats in Lower Valais and 18 in Upper Valais. *M. myotis* most commonly used orchards (64 % of the total frequency, Table 4) in Lower Valais, and in Upper Valais, it foraged mainly in meadows (58 %). Both in Upper and Lower Valais *M. myotis* foraged in woodland in the same proportion (27,9 % and 25 % respectively). *M. blythii* foraged mainly in steppe in Lower Valais (71,7 %, sum of the three steppe categories), it foraged in meadows (46,7 %), in open steppe (19 %), and in steppic pastures (10,3 %) in Upper Valais.

TABLE 3 : List of all the radiotracked bats. R. Arlettaz : radiotracking session between 1989 and 1993, E. Rey : radiotracking session in 2003.

Species	Ring number	observer	colony	Sex, age and reproductive state	Period	nights with transmitters	number of nights with recorded foraging activity	number of visited 1-ha cells	number of foraging areas (>5 1-ha cells)
<i>M. blythii</i>	409G	E. Rey	Fully	lactating adult female	8.07.03 - 16.07.03	8	6	13	1
<i>M. blythii</i>	416K	E. Rey	Fully	lactating adult female	27.06.03 - 4.07.03	14	4	7	1
<i>M. blythii</i>	430G	R. Arlettaz	Fully	adult male	04.09.89 - 20.09.89	17	7	37	1
<i>M. blythii</i>	514G	R. Arlettaz	Fully	pregnant adult female	03.07.90 - 09.07.90	7	4	22	1
<i>M. blythii</i>	745H	R. Arlettaz	Fully	immature female	29.08.91 - 03.09.91	6	3	22	1
<i>M. blythii</i>	710H	R. Arlettaz	Raron	lactating adult female	04.08.91 - 21.08.91	18	5	47	3
<i>M. blythii</i>	953G	R. Arlettaz	Raron	lactating adult female	11.08.91 - 22.08.91	12	2	48	2
<i>M. blythii</i>	962G	R. Arlettaz	Raron	lactating adult female	18.07.91 - 23.07.91	6	6	51	4
<i>M. blythii</i>	995G	R. Arlettaz	Raron	lactating adult female	02.08.91 - 04.08.91	4	2	36	1
<i>M. blythii</i>	997G	R. Arlettaz	Raron	immature male	14.08.91 - 23.08.91	10	3	46	1
<i>M. blythii</i>	999G	R. Arlettaz	Raron	lactating adult female	23.07.91 - 29.07.91	7	3	28	1
<i>M. blythii</i>	466G	R. Arlettaz	Naters	lactating adult female	24.07.90 - 29.07.90	6	6	44	1
<i>M. myotis</i>	062M	E. Rey	Fully	adult female	24.08.03 - 31.08.03	7	4	9	1
<i>M. myotis</i>	083G	R. Arlettaz	Fully	lactating adult female	26.06.90 - 30.06.90	5	4	34	2
<i>M. myotis</i>	090G	R. Arlettaz	Fully	lactating adult female	11.07.90 - 16.07.90	6	5	44	2
<i>M. myotis</i>	304M	E. Rey	Fully	lactating adult female	20.06.03 - 27.06.03	7	6	22	1
<i>M. myotis</i>	871G	E. Rey	Fully	lactating adult female	06.07.03 - 08.07.03	3	2	18	2
<i>M. myotis</i>	875M	E. Rey	Fully	adult female	18.07.03 - 24.07.03	6	4	18	2
<i>M. myotis</i>	877G	R. Arlettaz	Fully	immature female	03.09.91 - 05.09.91	3	3	19	1
<i>M. myotis</i>	749G	R. Arlettaz	Raron	lactating adult female	02.07.91 - 06.07.91	5	4	31	2
<i>M. myotis</i>	759G	R. Arlettaz	Raron	lactating adult female	06.07.91 - 08.07.91	3	2	19	2
<i>M. myotis</i>	763G	R. Arlettaz	Raron	lactating adult female	08.07.91 - 11.07.91/ 05.06.92 - 30.06.92	30	12	65	3
<i>M. myotis</i>	778G	R. Arlettaz	Raron	lactating adult female	16.07.91 - 18.07.91	3	2	29	1
<i>M. myotis</i>	824G	R. Arlettaz	Raron	lactating adult female	29.07.91 - 01.08.91/ 14.05.92 - 29.05.92	20	9	66	4
<i>M. myotis</i>	875G	R. Arlettaz	Raron	immature female	23.08.91 - 26.08.91	4	2	33	1
<i>M. myotis</i>	301G	R. Arlettaz	Naters	lactating adult female	30.07.90 - 07.08.90	9	7	22	1
Total						226	117	830	43
Mean						8,69	4,50	31,92	1,65
Standard deviation						1,26	0,47	3,11	0,18

### 3.3. Bat population density

#### 3.3.1. Population size

MARK ran 26 models for Upper Valais (Appendix 2). The three first models were selected with a time and group dependent capture probability and a group dependent population size (model A, QAIC = 925,02, model B, QAIC = 927,03, model C, QAIC = 927,06, Table 5). The first model with the time dependent parameters, except for the capture probability, is not selected for the best models (Model D, QAIC = 930,28). AICc weight gives a better idea of the best model. There is an important difference between the group of the first three models (AICc weight range from 0,38 for model A to 0,14 for models B and C) and the other (AICc weight = 0,03 for model D). Population size is quite constant through the three models A-B-C and shows an important variation with the other model, D (Table 5). The weighted average for the Upper Valais gives an estimation of the number of adult females of the population, there are  $282,05 \pm 20,70$  *M. myotis* and  $108,58 \pm 8,97$  *M. blythii*. So we have a total of  $390,63 \pm 29,67$  adult females of mouse-eared bats in Upper Valais. The capture probability for those three years is quite constant (Cormack-Jolly-Seber, model  $\phi(\cdot)p(t)$ ,  $p_{(1997)} = 0,544$ ,  $p_{(1998)} = 0,644$  and  $p_{(1999)} = 0,612$ ).

In Lower Valais, only 14 models were run (Appendix 2). This could be due to a non-constant capture probability in the last year of the sample (Cormack-Jolly-Seber, model  $\phi(\cdot)p(t)$ ,  $p_{(1997)} = 0,179$ ,  $p_{(1998)} = 0,133$  and  $p_{(1999)} = 0,382$ ) and also to the low capture probability itself. The three best models (A, B and C, Table 5) are time dependent only for the capture probability and group dependent only for the population size. Contrary to the Upper Valais models, the first parameters varying with time (model D) is the fourth model. But the AICc weights show an important loss of quality of this model, passing from 0,17 (model C) to 0,06 (model D). The population size, adult females, is not so fluctuating as in the Upper Valais model. It ranges between  $18,52 \pm 2,22$  for the lowest estimation (model B) and  $24,62 \pm 2,14$  for the highest estimation (model D). The weighted average gives an estimation of  $21,78 \pm 2,24$  adult females of mouse-eared bats ( $13,11 \pm 1,37$  *M. myotis* and  $8,67 \pm 8,97$  *M. blythii*).

#### 3.3.2. Bat population density

For the calculation of the population density in each area I take the weight averages for the population size and the Minimum Convex Polygon for the estimation of the surface (Fig. 2). The area for the population of Upper Valais is greater than in Lower Valais ( $189,17 \text{ km}^2$  vs.  $138,16 \text{ km}^2$ ). The density of bats is smaller in Lower Valais than in Upper Valais ( $0,16$  bats per  $\text{km}^2$  vs.  $2,07$  bats per  $\text{km}^2$ ).

TABLE 4 : Habitat frequency (1-Ha cells) and percentage of the habitats used by mouse-eared bats. The categories are described in Table 1 (Arlettaz 1999).

Habitat type	<i>M. myotis</i>				<i>M. blythii</i>			
	Lower Valais		Upper Valais		Lower Valais		Upper Valais	
	Freq	%	Freq	%	Freq	%	Freq	%
1.1 Cliff	-	-	2	0,8	-	-	-	-
1.2 Stony outcrop	-	-	-	-	1	0,9	-	-
1.3 Scree	-	-	-	-	-	-	1	0,3
1.4 Urbanised	-	-	3	1,1	-	-	-	-
1.5 Open fields	3	1,8	8	3,0	-	-	3	1,0
1.6 Vineyard	-	-	-	-	1	0,9	-	-
2.1 Fresh water	-	-	1	0,4	-	-	5	1,7
3.1 Steppe on stony outcrop or scree	-	-	-	-	37	33,6	21	7,0
3.2 Open steppe (<50% bushes)	-	-	1	0,4	26	23,6	59	19,7
3.3 Bushy steppe (>50% bushes)	-	-	1	0,4	16	14,5	6	2,0
3.4 Wooded steppe (<50% trees)	-	-	1	0,4	-	-	5	1,7
4.1 Steppic pasture	-	-	1	0,4	2	1,8	31	10,3
4.2 Xeric pasture or abandoned meadow	4	2,4	32	12,1	3	2,7	78	26,0
4.3 Wet pasture	-	-	3	1,1	-	-	-	-
5.1 Freshly cut, meagre meadow	-	-	39	14,7	2	1,8	-	-
5.2 Dense, meagre meadow	-	-	-	-	7	6,4	32	10,7
5.3 Freshly cut, mesophilous meadow	-	-	83	31,3	4	3,6	8	2,7
5.4 Dense, mesophilous meadow	2	1,2	14	5,3	8	7,3	30	10,0
7.1 Traditional orchard, apple	2	1,2	2	0,8	-	-	-	-
7.2 Traditional orchard, apricot	7	4,3	-	-	-	-	-	-
7.3 Intensively cultivated orchard	105	64	-	-	-	-	-	-
8.1 Xerothermic forest (oaks)	4	2,4	-	-	1	0,9	1	0,3
8.2 Xerothermic forest (other)	3	1,8	11	4,2	-	-	8	2,7
8.3 Chestnut forest	4	2,4	-	-	1	0,9	-	-
8.4 Riparian forest	4	2,4	5	1,9	-	-	3	1,0
9.1 Xerophilous forest	10	6,1	-	-	-	-	-	-
9.2 Xerophilous forest	11	6,7	12	4,5	-	-	5	1,7
10.1 Pine forest	-	-	25	9,4	-	-	3	1,0
10.2 Spruce forest	1	0,6	6	2,3	1	0,9	-	-
10.3 Larch forest	-	-	1	0,4	-	-	-	-
10.4 Mixed coniferous forest	4	2,4	14	5,3	-	-	1	0,3
total cells	164		265		110		300	
total of habitat type	14		21		14		18	

TABLE 5 : Selected models of the population analyses, A, B and C are the best models, based on the AICc weight and D is the first time dependent model.  $\phi$  = survival probability,  $p$  = capture probability,  $\lambda$  = population growth rate,  $N$  = population size, (.) = constant parameters, (g) = group-specific parameters, (t) = time-specific parameters, (g x t) = time and group specific parameters. The first line is the estimation for *M. myotis*, the second line is the estimation for *M. blythii* and the third line is the total of both species. All the estimations are for adult females.

### Upper Valais

Model	AICc Weight	Estimate $\pm$ SE	No of Parameters
A) $\phi(.)$ $p(g*t)$ $\lambda(.)$ $N(g)$	0.38196	284.47 $\pm$ 17.65	10
	0.38196	105.15 $\pm$ 6.78	10
		<b>389.62 <math>\pm</math> 24.43</b>	
B) $\phi(g)$ $p(g*t)$ $\lambda(.)$ $N(g)$	0.13996	282.23 $\pm$ 20.14	11
	0.13996	106.17 $\pm$ 8.54	11
		<b>388.42 <math>\pm</math> 28.68</b>	
C) $\phi(.)$ $p(g*t)$ $\lambda(g)$ $N(g)$	0.13796	282.65 $\pm$ 22.17	11
	0.13796	106.08 $\pm$ 10.04	11
		<b>388.73 <math>\pm</math> 32.21</b>	
D) $\phi(t)$ $p(t)$ $\lambda(g)$ $N(g)$	0.02752	222.57 $\pm$ 17.59	9
	0.02752	94.29 $\pm$ 7.56	9
		<b>316.86 <math>\pm</math> 25.15</b>	
Weighted Average, <i>M. myotis</i>		282.05 $\pm$ 20.70	
Weighted Average, <i>M. blythii</i>		108.58 $\pm$ 8.97	
Total		<b>390.63 <math>\pm</math> 29.67</b>	

### Lower Valais

Model	AICc Weight	Estimate $\pm$ SE	No of Parameters
A) $\phi(.)$ $p(t)$ $\lambda(g)$ $N(g)$	0.34335	12.67 $\pm$ 1.57	4
	0.34335	7.01 $\pm$ 1	4
		<b>19.68 <math>\pm</math> 2.57</b>	
B) $\phi(g)$ $p(t)$ $\lambda(t)$ $N(g)$	0.24548	11.76 $\pm$ 1.48	5
	0.24548	6.76 $\pm$ 0.74	5
		<b>18.52 <math>\pm</math> 2.22</b>	
C) $\phi(g)$ $p(t)$ $\lambda(.)$ $N(g)$	0.17817	12.54 $\pm$ 1.82	5
	0.17817	6.99 $\pm$ 0.90	5
		<b>19.53 <math>\pm</math> 2.72</b>	
D) $\phi(g)$ $p(t)$ $\lambda(.)$ $N(t)$	0.06559	12.31 $\pm$ 1.07	5
		<b>24.62 <math>\pm</math> 2.14</b>	
Weighted Average, <i>M. myotis</i>		13.11 $\pm$ 1.37	
Weighted Average, <i>M. blythii</i>		8.67 $\pm$ 0.87	
Total		<b>21.78 <math>\pm</math> 2.24</b>	

FIGURE 2 : Localisation of bat foraging grounds and of colony home range (MCP) of the three roosts. Fully, Raron and Naters (X) are the three colonies and Sion is the main city of the canton. The blue points are the hectares with foraging *M. myotis* and red points are the hectares with foraging *M. blythii*. The red polygon is the MCP for the Lower Valais population and the blue polygon is the MCP for the Upper Valais population.



### 3.4. Ecological Niche Factor Analysis

#### 3.4.1. *Myotis myotis*

The amount of specialization for *M. myotis* given by the marginality varies from a minimum of 0,34 (map B) to 0,35 (map A) and 0,41 (map C) (Table 6). Variables selected for the marginality factor are the three Human variables, orchards, meadows, pastures and the NDVI for the three species maps (map A, B and C). But there is an important difference between the map B and the maps A and C. The main variable for the marginality of the map B are the orchards and the vineyards and meadows, pastures, dense forest, roads and buildings are the main variables for map C (Table 6). The topographical variables seem to have a low influence on the greater mouse-eared bat. With the elevation and slopes variables, the bats are found in locations with lower values than average. Eastness has no effect and Northness is found with lower values than average with map B and with higher values than average with map C. On map C (best HS map chosen on the basis of the AVI = 0,74 and CVI = -0,00667, Table 7), *M. myotis* is found more often in pastures, meadows, orchards, roads, buildings and dense forest than the average and less often in unproductive vegetation and on slope and elevated areas. The values of global marginality (0,982) and of tolerance (0,452) (Table 9) for this species map show that *M. myotis* live in a particular habitat, with pastures, meadows and orchards, and that it is more or less tolerant towards deviation of the optimal habitat (all the results are in the Appendix 3).

#### 3.4.2. *Myotis blythii*

The part of the marginality factor explaining some specialization is greater for *M. blythii*. It ranges between 0,42 (map D) to 0,47 (map F) and 0,48 (map E) (Table 6). In the analyses of *M. blythii* the same differences appear between the maps D-F and the map E. The variables selected in the marginality are the Landsat – PCA2, NDVI, meadows, bushes, open forest and the three Human variables for the three maps. On map E, vineyards have a very high value for the marginality (0,812) and the other following variables are slopes, unproductive vegetation, bushes, bushy forest and open forest (Table 6). As with *M. myotis*, the elevation shows a negative correlation, meaning that the lesser mouse-eared bats were found in locations with lower values than average. All the results are in the Appendix 4. On map F (best map chosen on the basis of the AVI = 0,658 and CVI = -0,00323, Table 7) *M. blythii* is found more often in meadows, open forest, buildings, roads, vineyards and bushes and less often on slope and elevated areas. Bushy forest and unproductive vegetation are not selected, and the exposure (Eastness and Northness) play no role in the habitat of *M. blythii*. As with *M. myotis*, *M. blythii* live in a particular habitat (marginality = 0,876) and is lesser tolerant to a deviation of the optimal habitat than the greater mouse-eared bat (tolerance = 0,422) (Table 9).

### 3.5. Habitat suitability map

#### 3.5.1. *Myotis myotis*

The HS maps with the map A, B and C were computed with the marginality and the three first specialization factors. They explained 90 % (map A, B and C) of the global information. These values are composed of all the marginality, and of 80 % (map A, B and C) of the specialization. The values are the same for the three maps because it is the number of factors used that gives the explained information and specialization. The resulting maps are shown in Fig. 3b (map A), Fig. 4a (map B) and Fig. 4b (map C). The validation of the three habitat suitability maps are shown in Table 7, the AVI ranges from 0,698 (map B) to 0,74 (map C) and the CVI ranges from -0,00955 (map A) to -0,00115 (map B).

#### 3.5.2. *Myotis bythii*

HS maps computed for the map D and E included the marginality and the three first specialization factors. It explained 90,9 % of the global information and 81,9 % of the specialization for both maps D and E. For map F the marginality and the two first specialization factors were used, explaining 88,6 % of the global information and 77,2 % of the specialization. The resulting maps are shown in Fig. 3a (map D), Fig. 5a (map E) and Fig. 5b (map F). The validation of the HS maps are given in Table 7, the AVI ranges from 0,635 (map D) to 0,658 (map F) and the CVI ranges from -0,00942 (map D) and -0,0478 (map E).

TABLE 6 : Marginality values of the three analyses for *M. myotis* (up) and *M. blythii* (below). + means that the bats were found in locations with higher values than average, the symbol - the reverse. Map A-D : Valais species map; map B-E : Lower Valais species map; map C-F : Upper Valais species map. The Ecogeographical variables are described in Table 2

<i>Myotis myotis</i>						
Ecogeographical variables	Map A, marginality (35%)		Map B, marginality (34 %)		Map C, marginality (41 %)	
Elevation	----	-0,365	----	-0,359	---	-0,307
Slopes	--	-0,163	--	-0,171	-	-0,128
Northness	0	0,015	+	0,099	-	-0,059
Eastness	0	-0,007	0	-0,005	0	-0,006
LandsatPCA1	0	-0,041	0	0,025	-	-0,09
LandsatPCA2	0	0,016	0	0,039	0	-0,006
LandsatPCA3	-	-0,093	-	-0,133	0	-0,042
NDVI	+	0,107	+	0,115	+	0,081
Meadow	++++	0,367	++	0,221	++++	0,429
Pasture	+++	0,312	+	0,066	+++++	0,468
unproductive vegetation	--	-0,167	-	-0,122	--	-0,176
Orchards	++++	0,446	+++++	0,469	+++	0,349
Bushes	0	-0,045	0	-0,017	-	-0,061
Open forest	0	0,04	-	-0,054	+	0,113
Dense forest	++	0,153	0	0,034	++	0,228
Buildings	+++	0,283	++	0,159	+++	0,34
Roads	+++	0,328	++	0,233	++++	0,352
Vineyards	++++	0,379	+++++	0,653	+	0,08

<i>Myotis blythii</i>						
Ecogeographical variable	Map D, marginality (42 %)		Map E, marginality (48 %)		Map F, marginality (47 %)	
Elevation	----	-0,391	---	-0,273	----	-0,406
Slopes	0	0,025	++	0,159	-	-0,053
Northness	0	-0,02	0	-0,033	0	-0,01
Eastness	0	-0,042	0	-0,023	0	-0,047
LandsatPCA1	0	-0,025	0	0,045	-	-0,061
LandsatPCA2	+	0,105	+	0,144	+	0,069
LandsatPCA3	0	-0,04	-	-0,07	0	-0,017
NDVI	+	0,091	+	0,09	+	0,08
Meadow	++++	0,39	+	0,13	+++++	0,485
Mayen	0	-0,022	0	-0,001	0	-0,031
Unproductive vegetation	+	0,062	++	0,19	0	-0,017
Bushes	++	0,237	++	0,244	++	0,202
Bushy forest	0	0,031	++	0,151	0	-0,04
Open forest	+++	0,337	++	0,198	++++	0,372
Buildings	+++	0,303	+	0,104	++++	0,376
Roads	+++	0,325	+	0,135	++++	0,389
Vineyard	+++++	0,546	+++++	0,812	+++	0,325

## Results

TABLE 7 : Absolut Validation Index (AVI) and Contrast Validation Index (CVI) for the six habitat suitability maps. Standard deviation and confidence intervals are calculated by a 10-fold Jack-knife cross-validation. For *M. myotis*, map A : Valais species map; map B : Lower Valais species map; map C : Upper Valais species map, and for *M. blythii*, map D : Valais species map; map E : Lower Valais species map; map F : Upper Valais species map.

	Statistics	Species map	Mean $\pm$ SD	90% confidence interval
<i>Myotis myotis</i>	AVI	Map A	0,702 $\pm$ 0,0562	[0,615; 0,769]
		Map B	0,698 $\pm$ 0,0984	[0,556; 0,849]
		Map C	0,74 $\pm$ 0,0642	[0,647; 0,824]
	CVI	Map A	-0,00955 $\pm$ 0,0408	[-0,0755; 0,0427]
		Map B	-0,00115 $\pm$ 0,0984	[-0,143; 0,15]
		Map C	-0,00667 $\pm$ 0,0639	[-0,0964; 0,0818]
<i>Myotis blythii</i>	AVI	Map D	0,635 $\pm$ 0,143	[0,454; 0,853]
		Map E	0,643 $\pm$ 0,216	[0,317; 0,925]
		Map F	0,658 $\pm$ 0,0922	[0,524; 0,791]
	CVI	Map D	-0,00942 $\pm$ 0,126	[-0,168; 0,181]
		Map E	-0,0478 $\pm$ 0,18	[-0,319; 0,198]
		Map F	-0,00323 $\pm$ 0,091	[-0,136; 0,131]

TABLE 8 : Values of the mean calculated in each square on each habitat suitability map. Maximum distance and mean distance squares were constructed and centered on the three roosts, Fully, Raron and Naters. For *M. myotis*, map A : Valais species map; map B : Lower Valais species map; map C : Upper Valais species map, and for *M. blythii*, map D : Valais species map; map E : Lower Valais species map; map F : Upper Valais species map.

		<i>Myotis myotis</i>		<i>Myotis blythii</i>	
		maximum distance 25 km	mean distance 9 km	maximum distance 10 km	mean distance 4 km
Fully	Map A - D	26,93	38,33	41,27	45,54
	Map B - E	27,95	39,02	50,27	53,25
	Map C - F	26,27	37,79	37,11	42,04
Raron	Map A - D	18,36	28,03	31,67	48,38
	Map B - E	19,53	28,52	39,24	56,38
	Map C - F	17,65	27,66	27,92	44,20
Naters	Map A - D	16,81	24,78	28,92	53,27
	Map B - E	17,96	25,57	37,43	61,50
	Map C - F	16,12	24,10	24,73	48,97

TABLE 9 : Values of the global marginality, specialization and tolerance of the three species maps. The values found in Hausser (1995) for *M. myotis* are given for comparison.

	<i>Myotis myotis</i>				<i>Myotis blythii</i>		
	Map A	Map B	Map C	Hausser (1995)	Map D	Map E	Map F
Global marginality	1,022	1,222	0,982	0,53	0,893	1,067	0,876
Specialization	1,926	3,412	2,212	-	2,059	4,04	2,37
Tolerance	0,519	0,293	0,452	0,75	0,486	0,248	0,422

### 3.6. HS map comparison

There were significant differences between the habitat suitability mean value of the three species maps (Table 8) (Kruskall-Wallis, 1-way test, Chi<sup>2</sup> approximation, df = 2, for *M. myotis* : p = 0,0009 for the maximum distance and p = 0,0798 for the mean distance and for *M. blythii* : p < 0,0001 for the maximum and for the mean distance). There were also significant differences between the habitat suitability mean value of the three colonies (Kruskall-Wallis, 1-way test, Chi<sup>2</sup> approximation, df = 2, for both *M. myotis* and *M. blythii*: p < 0,0001 for the maximum and for the mean distance). The values of the HS maps ranges from 0 to 100. The subtraction of the HS maps gave ranges from -15 to +25 for *M. myotis* (Fig. 6a) and from -38 to +19 for *M. blythii* (Fig. 6b). For both species the HS maps have a narrower range of suitable habitat with the Upper Valais species map (map C for *M. myotis* and map F for *M. blythii*) than for the Lower Valais species map (map B for *M. myotis* and map E for *M. blythii*). The differences mainly occur on the peripheral of the suitable area (50 % suitable habitat all around the 90 % suitable habitat on the maps) and this is more visible on the map of *M. blythii* (Fig. 5a and Fig. 5b). The values of the global marginality, specialization and tolerance are also interesting for the comparison (Table 9). For both species, there is a difference between the map computed with the Lower Valais species map or with the Upper Valais species map. For more comparison the values found in Hausser (1995) are presented in the Table 9.

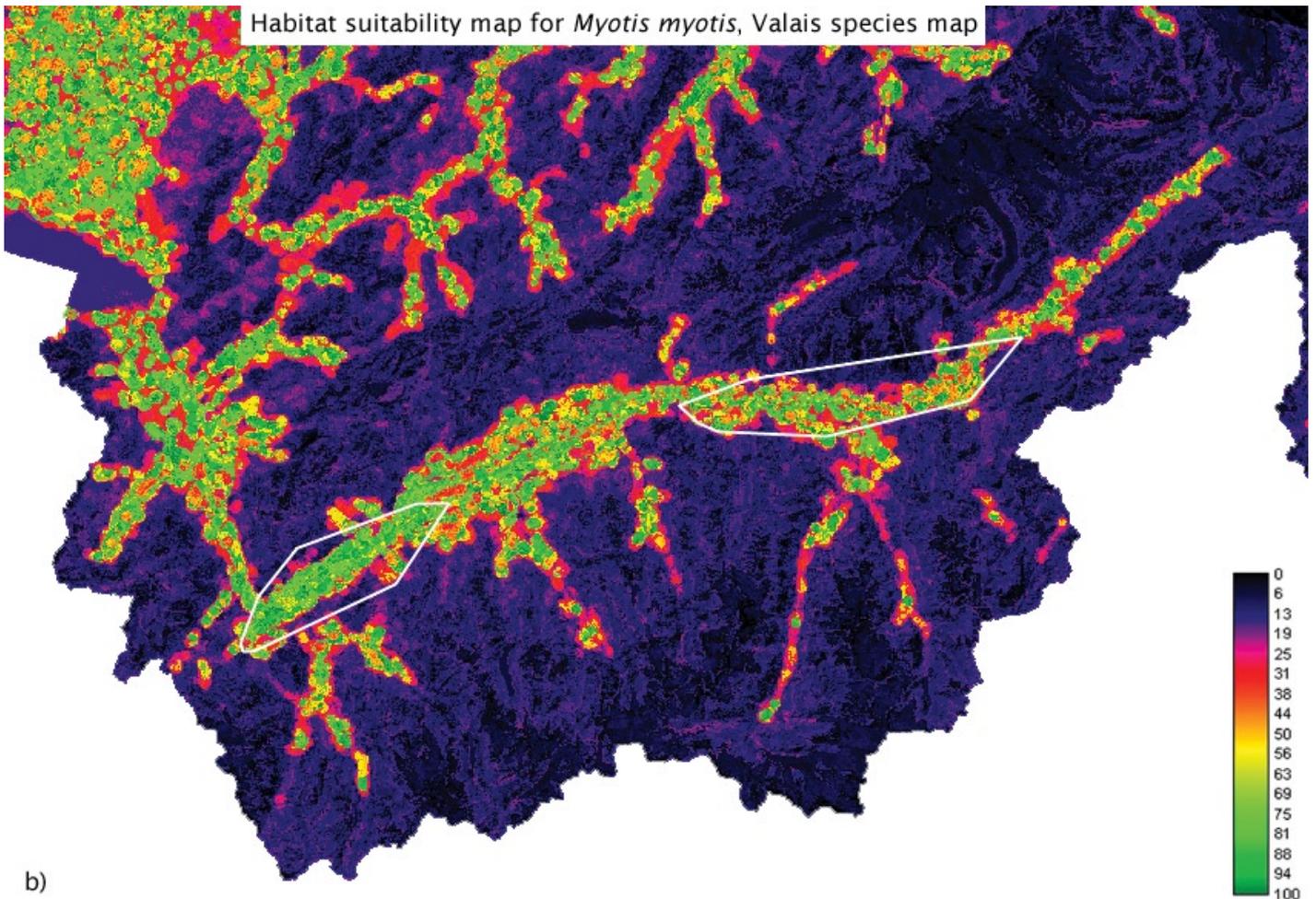
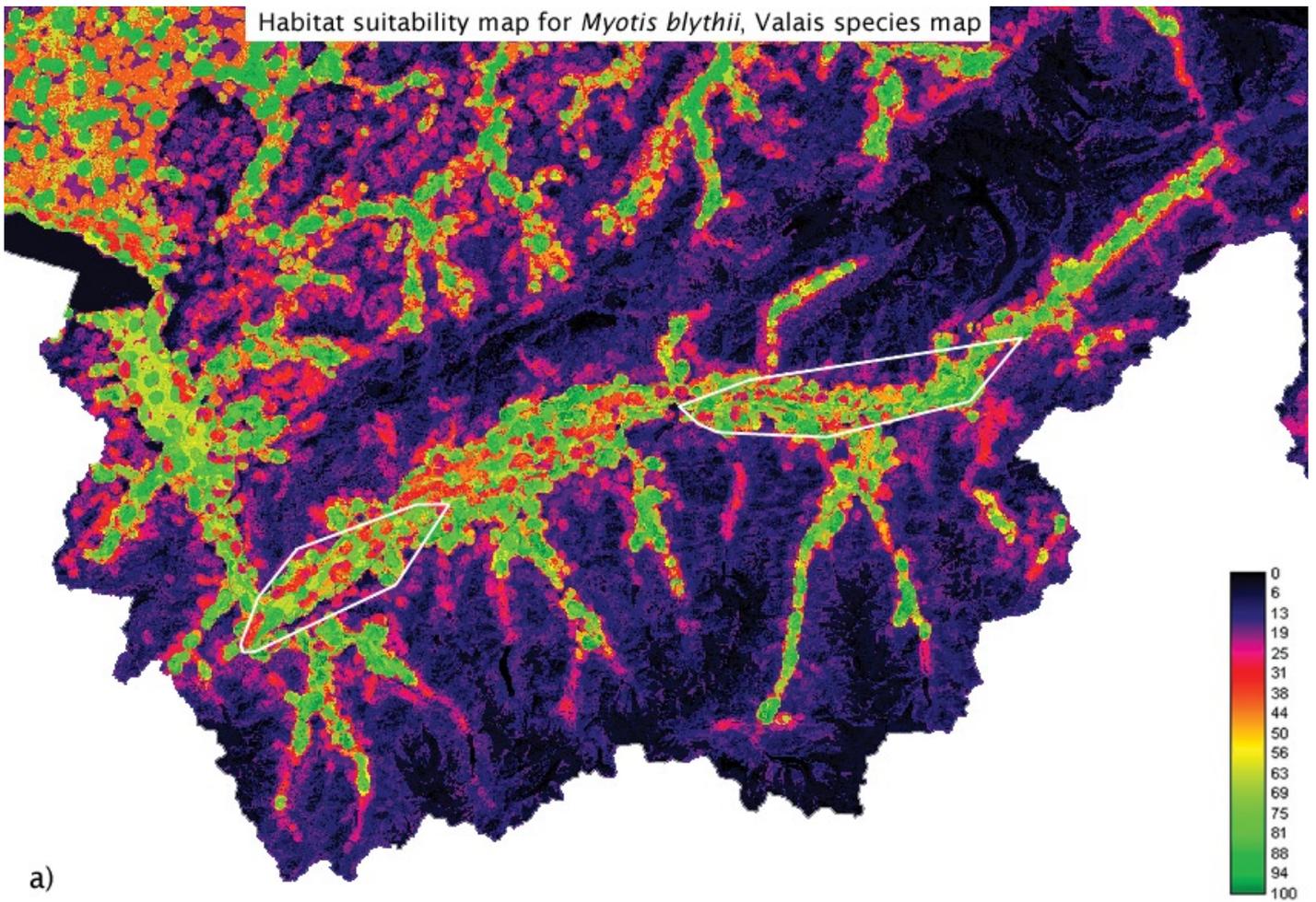


FIGURE 3: Habitat suitability maps for *M. blythii* (a) and *M. myotis* (b) both computed with the Valais species map. It corresponds to the maps A (*M. myotis*) and D (*M. blythii*) in the text. White polygons are the Minimum Convex Polygons of the Upper and Lower Valais populations.

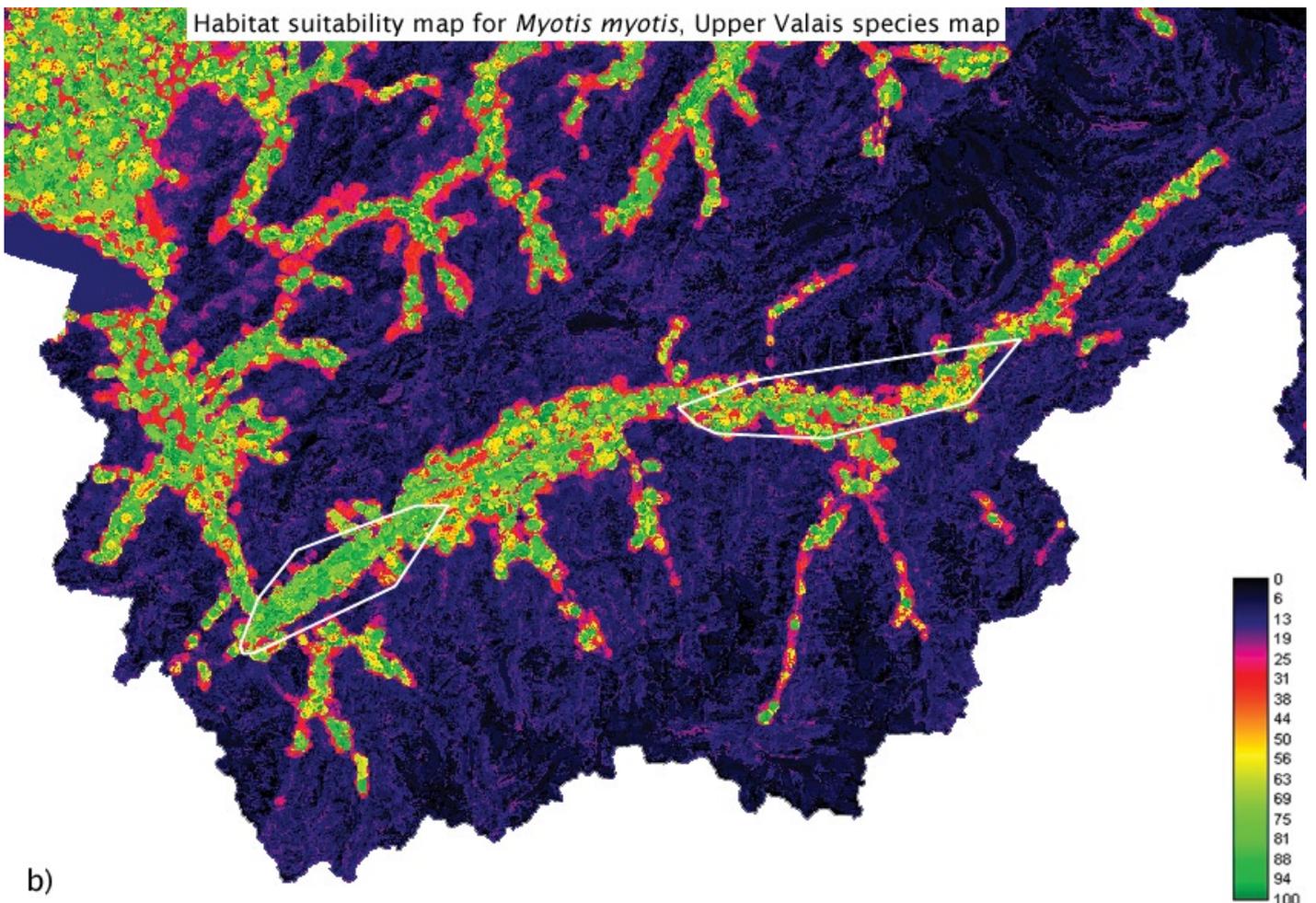
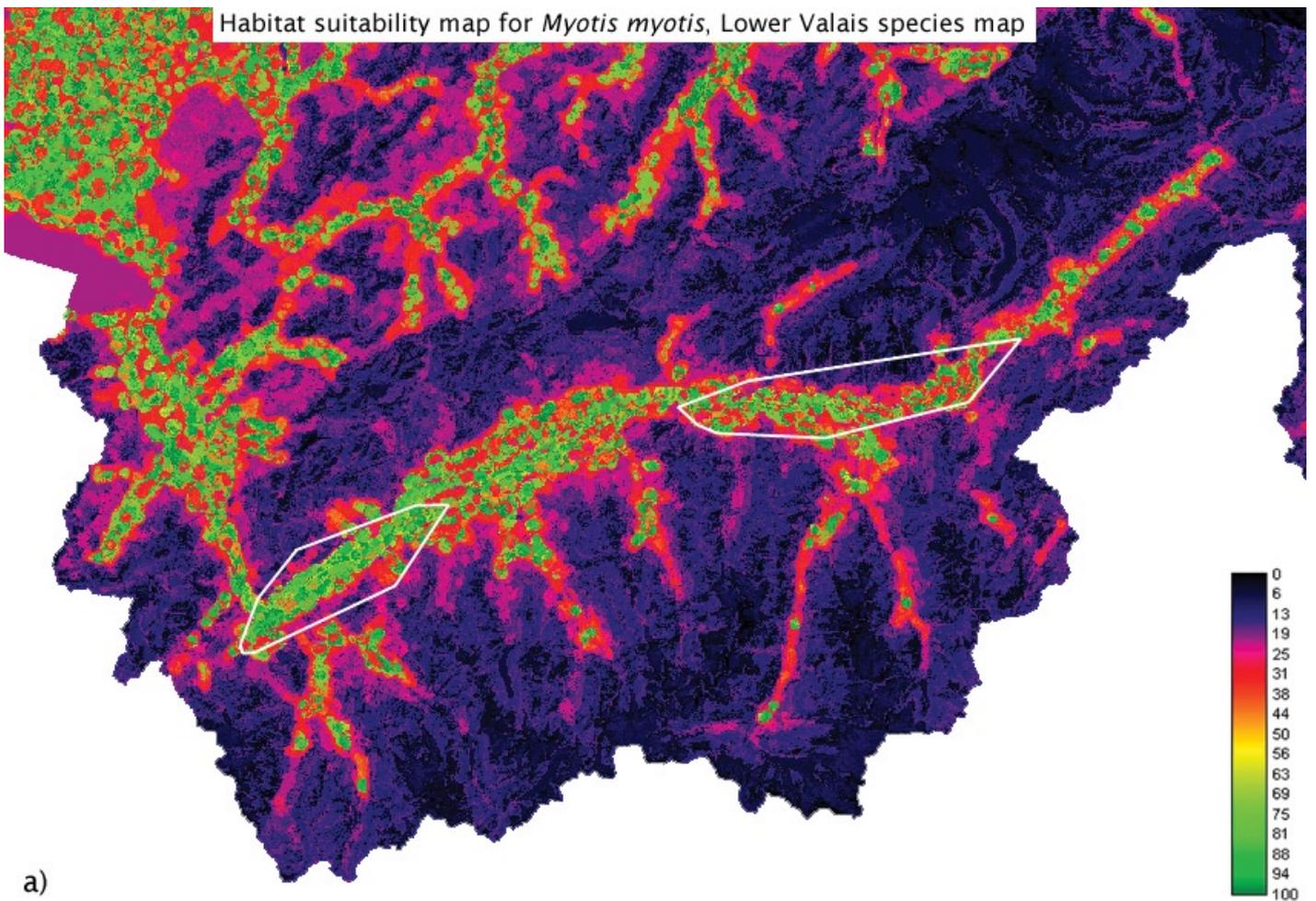


FIGURE 4: Habitat suitability maps for *M. myotis* computed with the Lower Valais species map (a) and with the Upper Valais species map (b). It corresponds to the map B (Lower Valais) and C (Upper Valais) in the text. White polygons are the Minimum Convex Polygons of the Upper and Lower Valais populations.

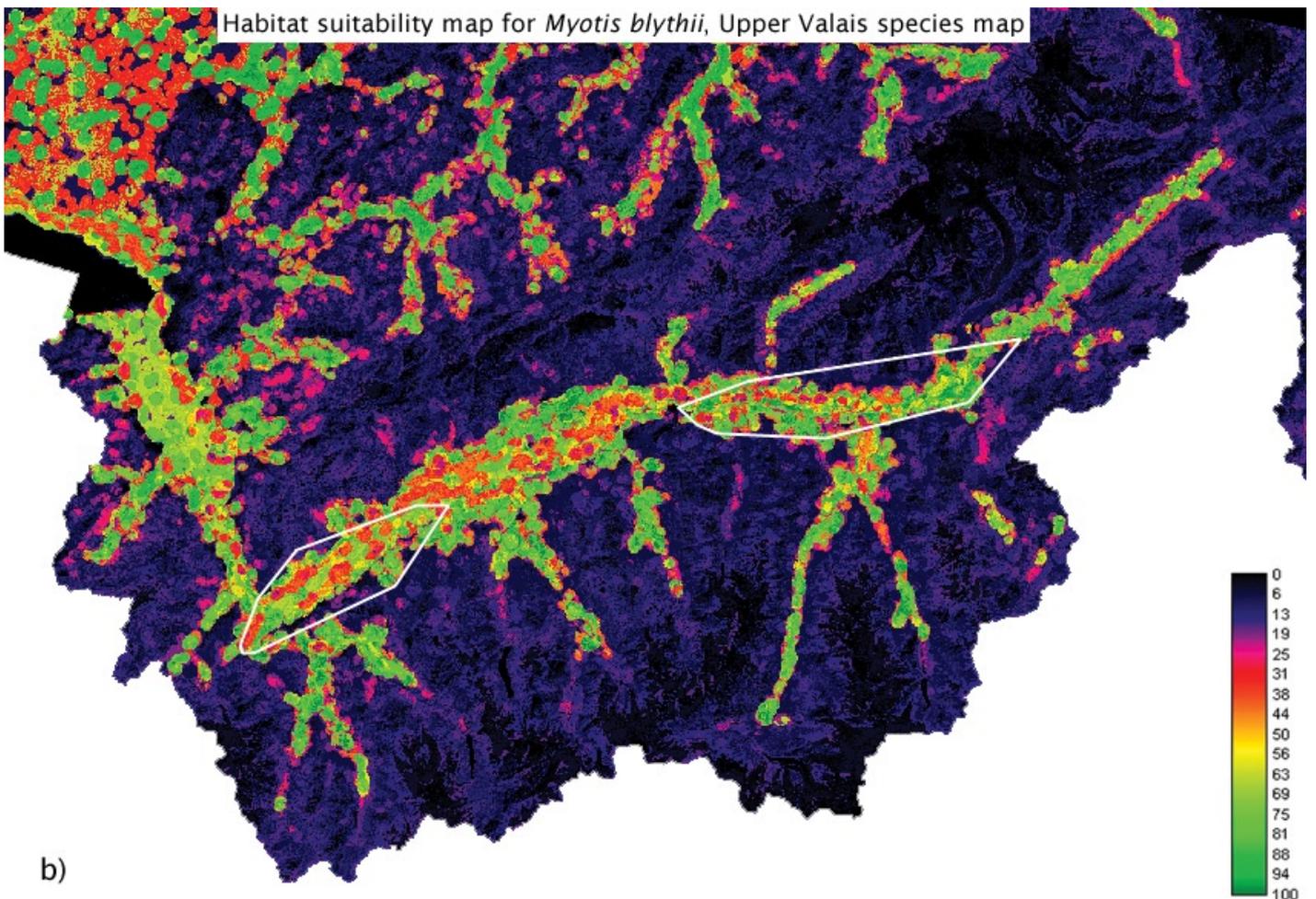
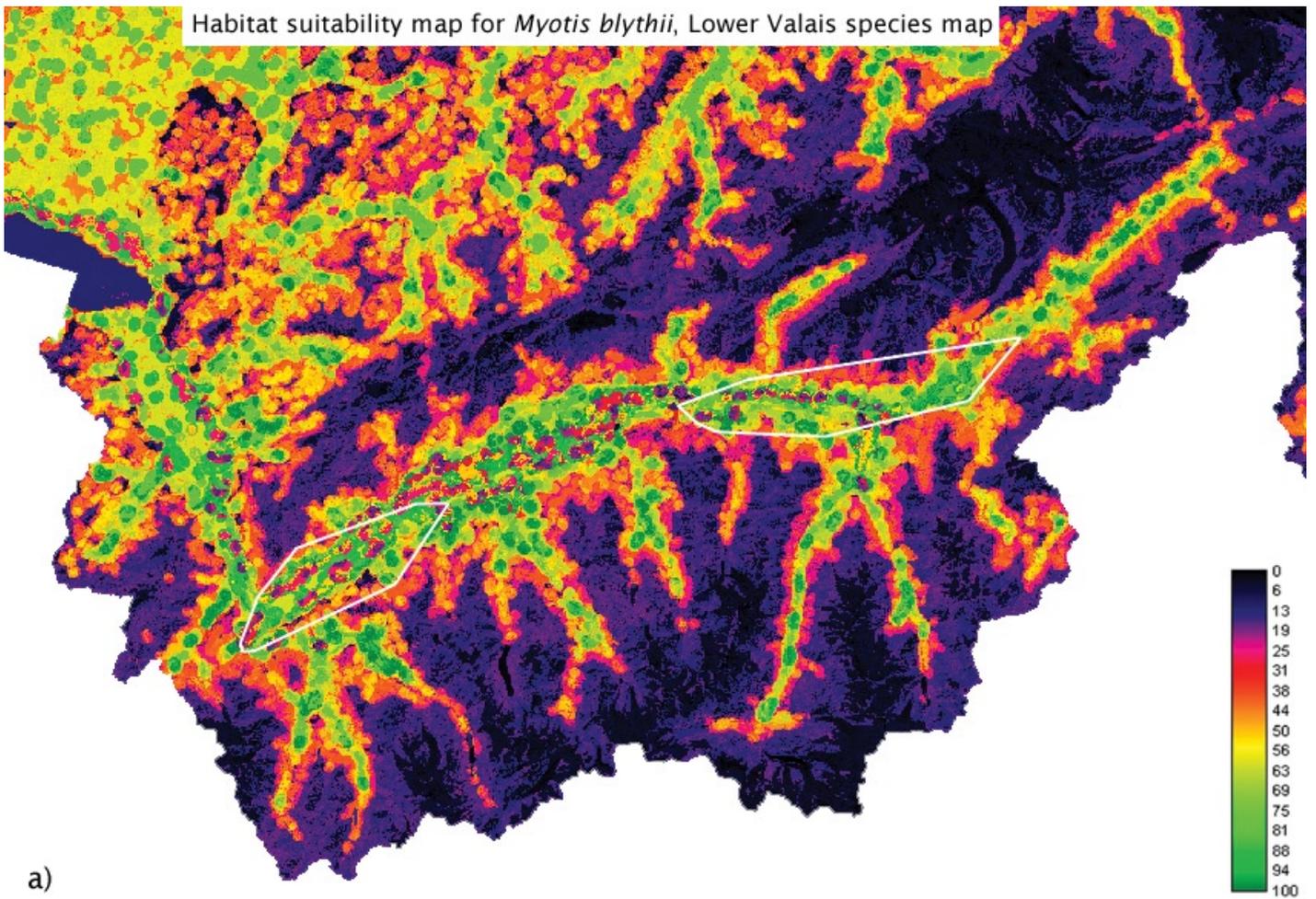


FIGURE 5: Habitat suitability maps for *M. blythii* computed with the Lower Valais species map (a) and with the Upper Valais species map (b). It corresponds to the map E (Lower Valais) and F (Upper Valais) in the text. White polygons are the Minimum Convex Polygons of the Upper and Lower Valais populations.

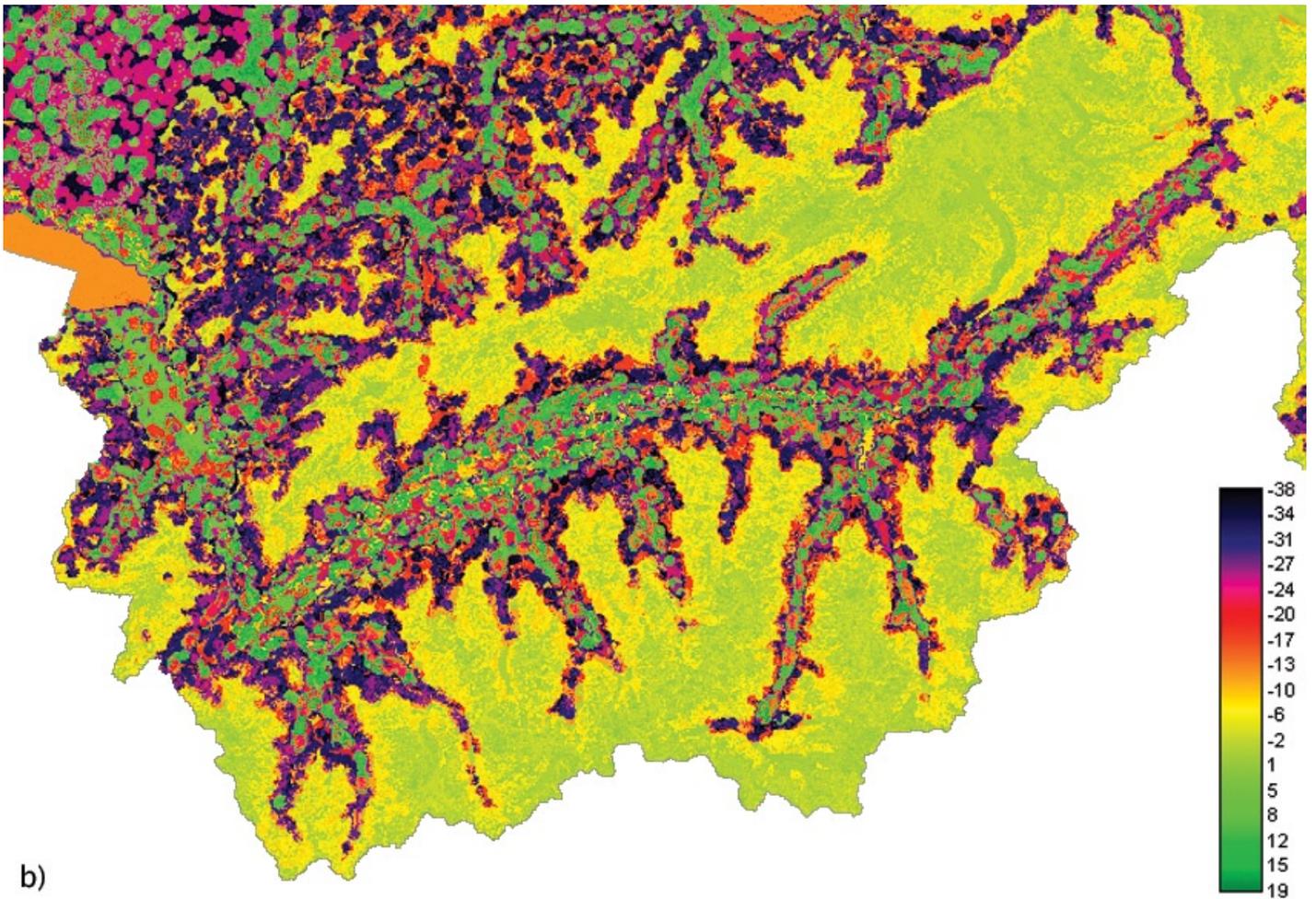
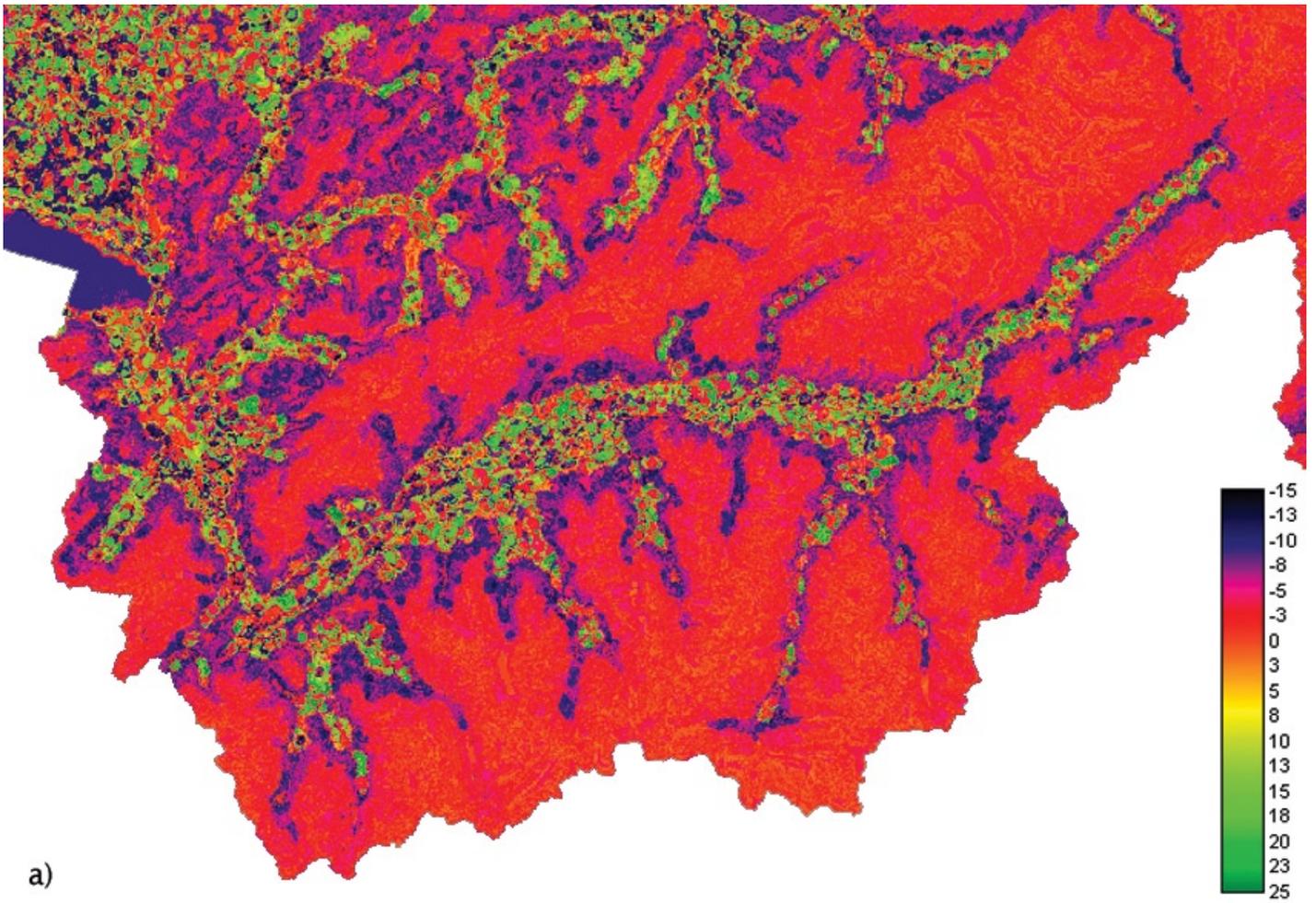


FIGURE 6 : Habitat suitability map comparison for *M. myotis* (a) and for *M. blythii* (b). The maps are calculated by subtracting the HS map computed with the Upper Valais species map minus the HS map computed with the Lower Valais species map.



## 4. Discussion

### 4.1. Habitat diversity

Litterature about landscape and the farming influence concludes to an impoverishment of the landscape structure in intensive farming systems (Bignal & McCracken 1996; van Mansfeld et al. 1998; Office Fédéral de la Statistique 2002 a,b; Kohli & Birrer 2003; Kleijn & Sutherland 2003). Bignal & McCracken (1996) and Kleijn & Sutherland (2003) noted the importance of low-intensity farming management in creating spatio-temporal biological diversity for several bird species in Great Britain. The Swiss Atlas of breeding birds (Schmidt et al. 1998) and the study of Kohli & Birrer (2003) also provided interesting maps of bird diversity in Switzerland. Both maps had higher bird diversity in Upper Valais than in Lower Valais. Other comparisons between organic agriculture (or extensive farming system) and conventional agriculture (or intensive farming system) conclude to an increase of diversity on extensive farming system with other indicators than birds. Working mainly on the landscape structure, van Mansfeld et al. (1998) could show that diversity of habitats is higher on extensive farms than on intensive farms and that landscape is more structured in those farming systems. The diversity of habitats is then more important in extensive farming system than in intensive farming system. This supportes our results, the Levins indices and the proportion of foraging habitats. The mouse-eared bats have more habitat available in Upper Valais than in Lower Valais.

In England, Walsh & Harris (1996b) found a difference of bat activity in the eastern part of the country, where the landscape is mainly composed of conventional agriculture. Recently, Wickramasinghe et al. (2003) gave a comparable conclusion at a lower scale (comparison of neighbouring intensive and extensive farming systems). Their results suggest that, compared with conventional agriculture, the habitat found on organic farms are of higher quality in terms of habitat structure and condition making them favourable foraging sites for small bats species. Nevertheless bats live in an urbanised and agricultural landscape where suitable areas patches are smaller than their home ranges. They can survive in such a landscape because they are able to move through open space to reach suitable habitats (Andrén 1994; Estrada 2002; Fenton 2003). However bats are vulnerable to habitat fragmentation mainly because the most costing variable for bats is the distance to the foraging areas and the patchiness of those areas. They have to visit more areas which were more distant from each other (Bright 1993; Estrada 2002). Even if *M. myotis* is flexible to the intensive exploitation of the area (Güttinger 1997; Drescher 2000) it cannot replace the removed suitable habitats in the vicinity of the roost. Wickramasinghe et al. (2003) and the final results finally support the fact that the intensification of the agriculture is a factor in the decline of mouse-eared bats because of an important removal of the landscape.

## 4.2. Bat population in Valais

The results of the population analysis are reliable even if the minimum number of years were used, and even if the capture probability is not constant through the years. An important bias could be created from the fact that there is no experimental design in the sampling of the ringing of bats. Nevertheless, if the results are compared with raw data the estimation of both populations are correct. In Upper Valais between 1995 and 2001, Christe et al. (2003) captured a total of 604 juveniles, females and males, of both *M. myotis* and *M. blythii* in the two roosts (Naters and Raron). From this field work a total of 230 adult females were ringed or controlled in 1999, and the estimation gives a total of nearly four hundreds adult females. The colony of the Lower Valais is investigated one or two times per year and it showed a decline this last decade. Since a camera was installed inside the colony, visual counting was done in 2002 and 2003. I counted a maximum of 28 bats on 17th July 2003 (12 juveniles recounted after the departure of the adults, personal observation). In 2002 14 individuals were ringed or controlled and no more than 12 juveniles were controlled in 2000. The population is very small but seems to be constant for the reference period (twenty-one adult females for the estimation).

Any comparisons of a bat population density with other studies are difficult because there are not often such analyses of population density. For instance, Bontadina (2002a) with *Rhinolophus hipposideros* calculated a density of almost six bats per hectare around the roost, but of 0,01 bat per hectare at 1200 m of the roost. Usually the surface used by the colony is not calculated, home range of individuals, distance to the foraging sites or density of bats within a given distance from the colony are given (Bontadina 2002b; Siero 1999; Güttinger 1997; Güttinger et al. 1998; Jaberg et al. 1998; Russo et al. 2002). Bright (1993) calculated a density of animals per hectare which is a mean density reported as often reached in favorable habitat. His density for *M. myotis* was of 0,01 bat per hectare in a suitable area. Comparing our results with this value, the density in Lower Valais show an unfavoured habitat as being ten times smaller than the prediction. Also, the difficulty to have good sample either for the population estimation or for the home range of the colony explains there is not so much analyses of the density of bats in the litterature.

## 4.3. Decline of bats

The causes of the decline of bats are numerous : roost removal, disturbance, predation, landscape removal, pesticide use and intensification of agriculture, etc. (Schober & Grimmberg 1991; Arlettaz 1995; Bontadina 2002b; Hartmann 2002). Concerning the mouse-eared bat's populations in Valais the problems caused by roost removal, disturbance and predation were minimized by the work of the Bat Conservation Group of Valais. A question that often arises in Bat Conservation Groups is that whether an active ringing policy could

have been a cause of the decline of bat populations. The three mixed colonies in Valais are studied from 1986. Intensive ringing sessions occurred in the three colonies and up to now we state an important decline only in Lower Valais. Moreover an overview of the ringing data show there was almost 200 individuals in the roost in Fully church in 1965 (M. Desfayes, database of the Bat Conservation group of Valais). In 1983, when Arlettaz et al. (1997b) monitored bat diversity in Valais, there was between 60 to 100 individuals ringed in the colony. In two decades the colony declined by 50% without any apparent disturbance such as capture and ringing.

Lower Valais is not the only highly intensive orchards' landscape where *M. myotis* are living. In South Tyrol (Drescher 2000) a colony of *M. myotis* arise to up to 1300 individuals. In a study on diet of the last thirty years, Drescher (2000) concluded that there was a changing of foraging area by greater mouse-eared bat during this period from oak shrub forest to orchards. The colony does not seem to have been influenced by the intensification of the environment in South Tyrol and the habitat loss could be more important in the Valais' particular case. The cause of removal of the habitats in Switzerland seems to be progressive urbanisation as most of the new buildings are constructed on agricultural landscape. This removal could have a slighter influence in the Swiss landscape or in South Tyrol for the greater mouse-eared bats, as there are enough other foraging areas to replace the removed one. This is unhappily not the case in Lower Valais. No other landscape is able to replace the removed foraging areas. Humans need place in the Rhône valley for its roads, buildings, railways, highway, for the agriculture and the Rhône itself also takes a wide part of the valley. Thus the removal has been more important in Lower Valais and could explain such a decline. The case of the lesser mouse-eared bat brings forward another problem of the intensive farming system, which is habitat removal by the agriculture itself. The number of farmers decreases as the size of the exploitations increases (Office Fédéral de la Statistique 2002a). This conduct to the use of more profitable landscape to the detriment of traditional agricultural landscapes such as meadows or steppic pastures. Those traditional landscape are replaced by bushy and open forest if the farmers do mow those areas any more. So both *M. myotis* and *M. blythii* suffer from a loss in habitat diversity.

#### 4.4. Niche of the mouse-eared bats

The Levins indices and the frequency of habitats gave a difference between the two areas and also gave an idea of the habitat available to the mouse-eared bats. We completed the analyses by modeling their niche occupancy. Niches seem to be different between Upper and Lower Valais. For *M. myotis*, there is a specialization or a focalization on the orchards in Lower Valais. The tolerance is very low indicating that *M. myotis* is not tolerant to a deviation of the optimal habitat which consists almost exclusively of orchards. The Upper Valais population exploits another niche composed by meadows, pastures and forests. As there are more different suitable and available habitats, the species is more tolerant there than in Lower Valais. Thus the population in Lower Valais is very small and it forages in very particular habitat, making it sensible to removal of their habitat (Bright 1993; Naves et al. 2003). *M. myotis* clearly forages in habitats in Lower Valais, which would not be used by the Upper Valais population. Two different populations at a distance of 100 kilometers exploit thus different habitats. It is also interesting to compare our results of the ENFA analyses (marginality and tolerance) to the results of Hausser (1995). The latter study, also an ENFA, are performed for whole Switzerland, and its results suggest that *M. myotis* is very tolerant to a deviation from its optimal habitat. This is not supported by our results of the three ENFA as Valais' population shows a stronger niche specialization than found by Hausser (1995). Niche occupancy is also different for *M. blythii* and the main difference is visible on the HS maps E and F as the lesser mouse-eared bat uses a wider range of suitable habitat in Lower Valais than in Upper Valais. On map E for *M. blythii* (Fig. 5a), all the 90% range of suitable habitat are surrounded by a 50% range of suitable habitat, which does not appear on map F (Fig. 5b). In Lower Valais, some *M. blythii* foraged in those 50% suitable habitat (personal observation). This results are also supported by the ENFA where the variables bushes, unproductive vegetation and slopes (which all define the steppic area where *M. blythii* foraged) are strongly selected on the Lower Valais species map analyses and almost not selected on the Upper Valais species map analyses. The tolerance for the Lower Valais species map is also low, indicating that the bats need to exploit less suitable areas which are actually the last suitable areas available for *M. blythii* in Lower Valais. The fact is that by modeling habitat with such used data (Lower Valais' data, map B, Fig. 4a and map E, Fig. 5a) we do not identify the good habitat, but either where the species could survive. Naves et al. (2003) demonstrated this case with the spanish brown bear (*Ursus arctos*). He also concluded that we cannot expect from a small population suffering from a long term regression to occupy all potential available habitats. A high proportion of suboptimal habitat (as for *M. blythii*) is a typical situation for many endangered species in highly humanised landscape.

#### 4.5. Limits of GIS analyses

GIS techniques are increasingly important for our understanding of animal distribution and resource selection (Millspaugh & Marzluff 2001). These techniques allow the biologists to make predictions at a relatively fine resolution. But the same predictions could have some important bias, given by the source of the variable used in the analysis or by the resolution of those variables. These two problems appear in this study with the meadows variable and the Human variables. Meadows are defined to be important by Arlettaz (1999). But the data from Geostat do not differ between extensive meadows and intensive meadows that usually have a lower prey availability. Arlettaz et al. (1997a) also showed an important difference in the diet diversity between Lower and Upper Valais. This conducts to an important bias as we did not include any qualitative variable that separate the extensive farming system and the intensive farming system. This could consist of pesticide residue in the soil or of arthropods diversity in the foraging areas. More differences between intensive vs. extensive farming system could appear if we include such a qualitative variable in the analyses. This could differentiate the quality of habitats found by the mouse-eared bats in Upper or in Lower Valais. The model done for the Chablais area (lower Rhône valley), where there is a colony of *M. myotis*, is biased because the intensive agriculture is completely different than in Fully (cereals vs. orchards). To be reliable, we should follow the *M. myotis* from the old colony of Roche to have a good comparison between the two intensive farming systems. The highly positive selection of the variables roads, vineyards and buildings brings forward another major bias of the analyses. In a densely populated plain as Valais, roads or buildings occur almost everywhere, and a majority of the hectares selected by the bats contains roads or buildings, so the correlation between these ecogeographical variable and the species presence data is very strong, even if these elements are not actually selected (Arlettaz 1999). The explanation of the selection of vineyards is also more difficult. Jaberg & Guisan (2001) found that vineyards were positively selected by four bat species. They explained this by the mild climate and thermophilous vegetation that such habitat creates. This corresponds to the ecological requirement of the mouse-eared bats, but it also was shown that bats avoided these areas (Arlettaz 1999). Vineyards occurs mainly on the periphery of the plain, exactly between the orchards and the upper steppe. This could be a bias from the analyses where vineyards are selected with the orchards (for *M. myotis*) or with the steppe (for *M. blythii*). It is also interesting to note that Jaberg & Guisan (2001) did not select any anthropogenic variable in their analyses (agricultural landscapes and orchards are considered as anthropogenic variable in their analyses). This is easily explained by the source of their sample, data came from capture sessions on water, from winter control of the cavities or from public intervention. No active search on potential foraging areas was done for this analysis, and it showed the important factors for the colonies and the winter cavities.



## 5. Conclusion

The general conclusion resulting from the different analysis of this study is that there is a difference in habitat diversity between Lower and Upper Valais. But the two bias as revealed in the former section can become objects for further studies. As no qualitative data are available in Valais regarding pesticides use, it would be interesting to sample the ground arthropods such as carabid beetles (*Carabidae*) or mole cricket (*Gryllotalpa gryllotalpa*) and to analyse the pesticides residues. It would be realistic to sample ground arthropods in the two bat population home ranges (Minimum Convex Polygons). The impact of the pesticides and chemical fertilisers on wildlife fauna are known for a long time. Birds, bats, insects and also the plants suffer from the intensive use of pesticides. This would be a method to quantify the amount of pesticides in the farmed landscape, and this will allow to compute a qualitative map for the two areas regarding the farming system. Landscape removal and urbanisation seemed to be one of the main cause of bats decline in the Rhône Valley. An historic review of the area in Lower Valais would be of interest. The review of the landscape during the five last decades in connection with the population dynamic of some umbrella species in Valais (birds, mouse-eared bats, grasshoppers, butterflies, ...) would reveal some interesting answers on the decline of the fauna in general in Lower Valais.

Before any further studies some important decisions must be taken by the administration itself. The first one concerns the urbanism. It is important not to relegate the orchards included in the triangle formed by Fully, Saillon and Saxon from farmland to urbanised-land. All the orchards included in this triangle are an important foraging area for *M. myotis*. Favorable foraging areas which are effectively used by the mouse-eared bats have to be maintained near the colony as the other foraging areas mainly used are near Ardon, 15 km away from Fully. *M. blythii* needs other decisions. The growing forest occupies the few residual steppe in Lower Valais. Forestry policy should maintain those meagre meadows and steppe by cutting all the bushes around. With such measures, those kind of environment rich both in fauna and flora will remain in Lower Valais. Finally the decision to be taken in Upper Valais is a constant help towards the extensive farms. Keeping those landscape is of importance not only for the mouse-eared bats but also for the Switzerland. Upper Valais is one of the last hot spots we have in the country, we then should keep protecting it (Schmidt et al. 1998; Kohli & Birrer 2003). Kleijn & Sutherland (2003) confirm this decision as changes in land-use intensity will have a greater impact on biodiversity in extensively farmed land than on intensively used farmland.

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APPENDIX 1 : Band and spatial resolution of the Landsat-5 Thematic Map (Table I) and description of the treatments of the Landsat imagery.

TABLE I : Band and spatial resolution of the Landsat-5 Thematic Map. The Band 6 was not used for the calculations.

Band	Wavelength ( $\mu\text{m}$ )	resolution (m)
Band 1	0,45 - 0,52	30
Band 2	0,52 - 0,60	30
Band 3	0,63 - 0,69	30
Band 4	0,76 - 0,90	30
Band 5	1,55 - 1,75	30
Band 6	10,40 - 12,50	60
Band 7	2,08 - 2,35	30

The Landsat imagery contains six bands all combined within the same file and they have to be separated. The information of the imagery is embedded in the specific reflectance of each band and it is this information that is used for the computation of the Normalized Difference Vegetation Index and for the Principal Component Analysis. The reflectance is the radiant flux which is reflected according to specific wavelength (see Table I), every band reflect in a particular wavelength range, from visible layer (Band 1 to 3) to invisible and infrared layer (Band 4 to 7). The Band 6 is in the thermic infrared range and is not used for the analyses. The bands were separated with the Av2idrisi extension in Arc View 3.2 (Schäuble 2003; ESRI 1992-1999) and it converts every band into an Idrisi 32 raster format (Eastmann 2003).

The resolution had to be uniformized between the EGVs and the Landsat maps. Species data and EGVs have a resolution of 100 m, whereas LANDSAT-5 TM has a resolution of 30 m. Since resolution did not need to be so accurate. I resampled the six TM bands with the resolution of the EGVs and then I calculated the vegetation index and the PCA. The pixels of the resampled image are a new derived value calculated by a bilinear interpolation. This technic consists of calculating a linear distance-weight average of the four closest cells for each pixel. Resampling and computation of the NDVI and the PCA were done with the GIS software Idrisi 32.

APPENDIX 2 : List of all models runned by MARK. Only 26 and 14, respectively for Upper Valais population and Lower Valais population were runned. QAIC (modified Akaike's criterion), deviance and the number of parameters are calculated by MARK.  $\phi$  = survival probability,  $p$  = capture probability,  $\lambda$  = population growth rate,  $N$  = population size, (.) = constant parameters, (g) = group-specific parameters, (t) = time-specific parameters, (g x t) = time and group specific parameters.

Models	QAIC	Number of Parameters	Deviance
<b>Upper Valais</b>			
$\phi(.)$ $p(g^*t)$ $\lambda(.)$ $N(g)$	925,02	10	28,5
$\phi(g)$ $p(g^*t)$ $\lambda(.)$ $N(g)$	927,03	11	28,45
$\phi(.)$ $p(g^*t)$ $\lambda(g)$ $N(g)$	927,06	11	28,48
$\phi(g)$ $p(t)$ $\lambda(.)$ $N(g)$	927,77	8	35,34
$\phi(.)$ $p(t)$ $\lambda(.)$ $N(g)$	928,73	7	38,33
$\phi(g)$ $p(g^*t)$ $\lambda(g)$ $N(g)$	929,09	12	28,45
$\phi(g)$ $p(t)$ $\lambda(g)$ $N(g)$	929,34	9	34,87
$\phi(.)$ $p(t)$ $\lambda(g)$ $N(g)$	929,9	8	37,46
$\phi(t)$ $p(t)$ $\lambda(g)$ $N(g)$	930,28	9	35,81
$\phi(t)$ $p(t)$ $\lambda(.)$ $N(g)$	930,57	8	38,14
$\phi(.)$ $p(g^*t)$ $\lambda(g)$ $N(.)$	935,85	10	39,32
$\phi(.)$ $p(g^*t)$ $\lambda(g)$ $N(t)$	935,85	10	39,32
$\phi(g)$ $p(g^*t)$ $\lambda(g)$ $N(.)$	937,88	11	39,3
$\phi(g)$ $p(g^*t)$ $\lambda(g)$ $N(t)$	937,88	11	39,3
$\phi(g)$ $p(g^*t)$ $\lambda(.)$ $N(.)$	945,53	10	49
$\phi(g)$ $p(g^*t)$ $\lambda(.)$ $N(t)$	945,53	10	49
$\phi(.)$ $p(t)$ $\lambda(g)$ $N(.)$	961,05	7	70,66
$\phi(.)$ $p(t)$ $\lambda(g)$ $N(t)$	961,05	7	70,66
$\phi(g)$ $p(t)$ $\lambda(.)$ $N(.)$	973,76	7	83,37
$\phi(g)$ $p(t)$ $\lambda(.)$ $N(t)$	973,76	7	83,37
$\phi(.)$ $p(t)$ $\lambda(t)$ $N(.)$	1016,74	7	126,34
$\phi(.)$ $p(t)$ $\lambda(t)$ $N(t)$	1016,74	7	126,34
$\phi(t)$ $p(t)$ $\lambda(.)$ $N(.)$	1016,74	7	126,34
$\phi(t)$ $p(t)$ $\lambda(.)$ $N(t)$	1016,74	7	126,34
$\phi(t)$ $p(t)$ $\lambda(t)$ $N(.)$	1016,74	7	126,34
$\phi(t)$ $p(t)$ $\lambda(t)$ $N(t)$	1016,74	7	126,34
<b>Lower Valais</b>			
$\phi(.)$ $p(t)$ $\lambda(g)$ $N(g)$	52,86	4	28,09
$\phi(g)$ $p(t)$ $\lambda(t)$ $N(g)$	53,53	5	26,25
$\phi(g)$ $p(t)$ $\lambda(.)$ $N(g)$	54,17	5	26,89
$\phi(g)$ $p(t)$ $\lambda(.)$ $N(.)$	56,17	5	28,89
$\phi(g)$ $p(t)$ $\lambda(.)$ $N(t)$	56,17	5	28,89
$\phi(g)$ $p(t)$ $\lambda(t)$ $N(.)$	57,2	2	37,11
$\phi(g)$ $p(t)$ $\lambda(t)$ $N(t)$	57,2	2	37,11
$\phi(g)$ $p(t)$ $\lambda(g)$ $N(g)$	58,79	2	38,7
$\phi(.)$ $p(t)$ $\lambda(t)$ $N(g)$	61,16	2	41,07
$\phi(.)$ $p(t)$ $\lambda(.)$ $N(g)$	67,38	7	34,69
$\phi(.)$ $p(t)$ $\lambda(.)$ $N(.)$	70,57	4	45,8
$\phi(.)$ $p(t)$ $\lambda(.)$ $N(t)$	70,57	4	45,8
$\phi(.)$ $p(t)$ $\lambda(t)$ $N(.)$	75,08	7	42,39
$\phi(.)$ $p(t)$ $\lambda(t)$ $N(t)$	75,08	7	42,39

APPENDIX 3 : Results of the ENFA analyses for *M. myotis* for the 18 ecogeographical variables. Marginality factor : The symbol + means that the greater mouse-eared bat was found in locations with higher values than averages. The symbol - means the reverse. Spec. = specialization, the greater the number of symbols, the higher the correlation. 0 indicates a weak correlation.

Map A, *Myotis myotis*

	marginality (35%)	spec. 2 (27%)	spec. 3 (9%)	spec. 4 (6%)	spec. 5 (5%)	spec. 6 (3%)	spec. 7 (3%)	spec. 8 (2%)	spec. 9 (2%)	spec. 10 (2%)	spec. 11 (2%)	spec. 12 (1%)	spec. 13 (1%)	spec. 14 (1%)	spec. 15 (1%)	spec. 16 (0%)	spec. 17 (0%)	spec. 18 (0%)
Elevation	----	*	0	0	***	****	*	0	0	***	****	*	0	***	****	0	0	0
Slopes	---	0	****	0	***	0	*	0	0	***	***	*	0	***	***	0	0	0
Northness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eastness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LandsatPCA1	0	****	0	0	***	***	****	0	0	***	***	0	0	0	0	0	0	0
LandsatPCA2	0	****	0	0	***	***	****	0	0	***	***	0	0	0	0	0	0	0
LandsatPCA3	0	****	0	0	***	***	****	0	0	***	***	0	0	0	0	0	0	0
NDVI	-	0	****	0	***	***	****	0	0	***	***	0	0	0	0	0	0	0
Meadow	++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture	++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unproductive vegetation	---	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orchards	++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bushes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open forest	++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dense forest	++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buildings	++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Roads	++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vineyard	+++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Map B, *Myotis myotis*

	marginality (34%)	spec. 2 (39%)	spec. 3 (8%)	spec. 4 (6%)	spec. 5 (3%)	spec. 6 (2%)	spec. 7 (2%)	spec. 8 (1%)	spec. 9 (1%)	spec. 10 (1%)	spec. 11 (1%)	spec. 12 (1%)	spec. 13 (0%)	spec. 14 (0%)	spec. 15 (0%)	spec. 16 (0%)	spec. 17 (0%)	spec. 18 (0%)
Elevation	----	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slopes	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northness	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eastness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LandsatPCA1	0	****	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LandsatPCA2	0	****	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LandsatPCA3	0	****	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NDVI	+	****	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meadow	++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unproductive vegetation	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orchards	+++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bushes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open forest	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dense forest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buildings	++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Roads	++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vineyard	+++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Map C, *Myotis myotis*

	marginality (41%)	spec. 2 (22%)	spec. 3 (10%)	spec. 4 (6%)	spec. 5 (5%)	spec. 6 (3%)	spec. 7 (3%)	spec. 8 (2%)	spec. 9 (1%)	spec. 10 (1%)	spec. 11 (1%)	spec. 12 (1%)	spec. 13 (1%)	spec. 14 (1%)	spec. 15 (0%)	spec. 16 (0%)	spec. 17 (0%)	spec. 18 (0%)
Elevation	----	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slopes	---	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northness	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eastness	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LandsatPCA1	0	****	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LandsatPCA2	0	****	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LandsatPCA3	0	****	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NDVI	+	****	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meadow	+++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pasture	+++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unproductive vegetation	---	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orchards	+++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bushes	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open forest	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dense forest	++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buildings	++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Roads	++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vineyard	+++++	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX 4 : Results of the ENFA analyses for *M. blythii* for the 18 ecogeographical variables. Marginality factor : The symbol + means that the lesser mouse-eared bat was found in locations with higher values than averages. The symbol - means the reverse. Spec. = specialization, the greater the number of symbols, the higher the correlation. 0 indicates a weak correlation.

Map D. *Myotis blythii*

	spec.2 (23%)	spec.3 (8%)	spec.4 (6%)	spec.5 (4%)	spec.6 (3%)	spec.7 (2%)	spec.8 (2%)	spec.9 (1%)	spec.10 (1%)	spec.11 (1%)	spec.12 (1%)	spec.13 (1%)	spec.14 (1%)	spec.15 (1%)	spec.16 (0%)	spec.17 (0%)
Elevation	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Slopes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eastness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LandsatPCA1	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
LandsatPCA2	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
LandsatPCA3	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
NDVI	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Meadow	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Mayen	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Unproductive vegetation	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Bushes	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Bushy forest	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Open forest	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Buildings	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Roads	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Vineyard	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***

Map E. *Myotis blythii*

	spec.2 (24%)	spec.3 (13%)	spec.4 (6%)	spec.5 (2%)	spec.6 (2%)	spec.7 (1%)	spec.8 (1%)	spec.9 (1%)	spec.10 (1%)	spec.11 (0%)	spec.12 (0%)	spec.13 (0%)	spec.14 (0%)	spec.15 (0%)	spec.16 (0%)	spec.17 (0%)
Elevation	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Slopes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eastness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LandsatPCA1	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
LandsatPCA2	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
LandsatPCA3	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
NDVI	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Meadow	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Mayen	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Unproductive vegetation	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Bushes	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Bushy forest	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Open forest	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Buildings	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Roads	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Vineyard	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***

Map F. *Myotis blythii*

	spec.2 (24%)	spec.3 (7%)	spec.4 (5%)	spec.5 (4%)	spec.6 (3%)	spec.7 (2%)	spec.8 (2%)	spec.9 (1%)	spec.10 (1%)	spec.11 (1%)	spec.12 (1%)	spec.13 (1%)	spec.14 (1%)	spec.15 (0%)	spec.16 (0%)	spec.17 (0%)
Elevation	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Slopes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eastness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LandsatPCA1	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
LandsatPCA2	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
LandsatPCA3	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
NDVI	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Meadow	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Mayen	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Unproductive vegetation	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Bushes	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Bushy forest	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Open forest	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Buildings	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Roads	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Vineyard	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***

