Habitat selection by foraging wrynecks *Jynx torquilla* during the breeding season: identifying optimal species habitat

Wendehals *Jynx torquilla*

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Abstract

1. Agricultural management has undergone a strong intensification in the last century, which included increased use of fertilizers, pesticides and elimination of natural structures (e.g. hedges). Such alterations have caused a decrease in species diversity, including farmland bird species, which rely on a manifold landscape matrix in order to acquire food and nesting resources. Many granivorous and insectivorous birds foraging on the ground rely on short and not too dense vegetation for efficient foraging. Vegetation structures and any changes thereof thus have an impact on food exploitation patterns, i.e. ultimately on survival, reproduction and population growth. Knowing specie's optimal habitat profile is thus prerequisite to elaborating conservation actions.

2. Since the end of 19th century the populations of the wryneck *Jynx torquilla* have been declining all over Europe. The reasons for the decline are not clear. Habitat loss, lack or reduction of ants (the main prey of wrynecks), climatic change and use of chemicals in agriculture are possible causes.

3. Seven wrynecks were radiotracked in Valais (SW Switzerland) to study the foraging habitat use during reproduction. Several habitat variables were mapped at each foraging location and compared with locations selected randomly within the individual's home range.

4. Wrynecks preferentially foraged at places with fragmentary vegetation with ≥ 50% bare ground. Vegetation height was not important. Old and medium - aged orchards and fallow land were the preferred foraging habitats.

5. Conservation measures should concentrate on preserving manifold and semi-open agricultural landscape matrices with loose ground vegetation cover so as to provide suitable foraging conditions.

Key words: Jynx torquilla, habitat utilisation, radiotracking

1. Introduction

The management of farmland has significantly changed in most parts of Europe in the last century (Tucker et al. 1994, Pain and Pienkowski 1997, Vickery et al. 2001, Robinson 2002, Benton 2002). Changes involve increase in fertilizer and chemical inputs, new stocking practices, silage production and maximization of harvest yield (Pain and Pienkowski 1997, Robinson 2002).

Farmland harbours many animal species, and such changes dramatically affect their habitat selection pattern. More homogeneous vegetation with fewer plant species reduces the possibilities of ecological niches for invertebrates, mammals and birds (Benton 2002). This has resulted in a broad decline in species richness, especially over the last 50 years (Fuller et al. 1995). Many formerly common farmland bird species (both granivorous and insectivorous) have declined dramatically. For example, granivorous birds rely on diversely composed vegetation, whereas insectivorous species need sufficient availability of and access to prey (McCracken 2004). Animals select their habitat in such a way that individual's survival, reproductive success and fitness are enhanced. An individual may use different cues to select its habitat: good food reservoirs, suitable nest sites, presence of mates and/or predation risk (Wiens 1989).

Habitat selection can be looked at as a hierarchical spatial process (Wiens 1989, Rolstad et al. 2000). In most cases it is practical to distinguish two spatial scales for habitat selection: 1) general habitat use, where preferred or avoided habitat types within the home range are identified, 2) microhabitat use, i.e. identification of the characteristics of sites where food items are collected. Here the focus is on the fine-grained selection of vegetation structures within preferred habitat types.

The selection of an appropriate habitat is particularly crucial during the breeding season because of high food demand by young for optimal development (Britschgi et al. 2006). It has repeatedly been demonstrated that the reproductive output depends on habitat quality (Jenny 1990, Tye 1992, Vickery et al. 2001, Pärt 2001, Poeplau 2005), which itself is positively correlated with the amount of available food. This availability of food depends mainly on two factors: food abundance and accessibility (Atkinson 2004, Butler et al. 2005). Atkinson et al. (2005) found that locations with a combination of short sward height and bare ground were favoured by many bird species, even though the abundance and richness of the main prey (invertebrates and small mammals, respectively) was higher at locations with high vegetation. Birds' access to food thus principally depends on vegetation density and structure (Birrer et al. 2002, Aschwanden et al. 2005, Atkinson et al. 2005).

Changes in agricultural landscape and associated altered habitat structures are possible reasons for the decline of the European wryneck *Jynx torquilla* since about 1950 (Glutz von Blotzheim 1980, Roselaar 1985, Heimer 1992). In Switzerland, mainly the populations in the northern and central parts have decreased (Glutz von Blotzheim 1980, Roselaar 1985, Keller et al. 2001); populations in the Alps and Ticino showed less variation

(Schaub and Lüthy 1998). The reasons for the decline are not known. Habitat changes resulting in declining number of nest sites and food resources, climatic change, and use of chemicals in agriculture are mentioned, but no scientific evidence backs it (Menzel 1968, Glutz von Blotzheim 1980, Poeplau 2005).

One first reason for the decline may be reduced food accessibility due to more intensive farming practices, in particular the use of fertilizers, which have caused the vegetation to grow faster and denser. A second reason may be the decline of the food resources themselves. Ground-dwelling ants, the main prey of wrynecks (Glutz von Blotzheim 1980, Hölzinger 1992, Freitag 1998), may have declined due to more intensive farming practices: sun radiation on terrestrial nests is important for ant reproduction, and may be hampered by a denser vegetation cover (Seifert 1996).

The habitat use of wrynecks has been investigated with radiotracking by Freitag (1998) and Poeplau (2005) who focussed on general habitat use. However, as long as microhabitat requirements are not identified, it remains impossible to tell apart these two factors, reduced food accessibility and availability, so as to suggest appropriate conservation measures. This study attempts to fill up this gap and to formulate recommendations for an optimal foraging habitat management in this threatened species.

2. **Material and methods**

The study was carried out on the plain along the river Rhone between Martigny and Sierre in the Canton of Valais (SW Switzerland, 46° 14' N, 7° 22' E). The study area has an extension of about 64 km^2 (1.6 x 40 km). The plain is used intensively for agricultural purposes, especially for cultivation of dwarf fruit trees and vineyards, but pastures, meadowland and vegetable gardens are also present. Except along the river, tall trees are scarce and the availability of natural cavities is therefore very limited. In this area 712 nest boxes have been installed between 1997 and 2003 that serve as nesting opportunities for wrynecks. From 2002 to 2006, between 37 and 92 (yearly mean: 67 ± 19.89) broods have been recorded (Reichlin 2006, unpubl.).

Wrynecks were caught either with mistnets mounted in front of the entry to the nesting box or with a special small net ("Kescher") that was held in front of the nest hole to catch individuals flying out of the box (Rolstad et al. 2000). The captured birds were measured according to the usual guidelines for Swiss ringers (body mass, HS3, tarsus length) and were equipped with radio transmitters (Holohil Systems Ltd., Canada, BD-2-P, 0.9 - 1.3g, activity sensor, lifespan 42 days). Our tags were below 5% of a bird's body mass (upper threshold ca 1.7 g according to Freitag (1998)).

The transmitters were fixed with a harness of two elastic rubber lashes around the legs. The used lash span was 110 mm, but had to be corrected for small individuals. The equipped birds were released immediately after tagging.

Radiotracking started when chicks were older than four days, i.e. when the adults started to intensify feeding (Geiser et al. in review). Due to the secretive and elusive behaviour of wrynecks (Menzel 1968, Glutz von Blotzheim 1980), the homing–in on the animal method (Samuel et al.1996) was used to locate radio-tagged birds. Additionally, we attempted to observe foraging birds so as to collect more information about their hunting tactic. The birds were usually approached from two different directions by two observers, this in order to enhance localisation and to collect a maximum of data. Although active foraging could only be confirmed at few precise locations, we assumed that most refer to search for food given that radiotracking sessions took place during the peak of food provisioning to young (Geiser et al. in review). Observations were carried out at different daytimes in order to get a good overview of the habitat exploitation. We collected ≥ 20 locations per bird, which lasted between one to five days. In order to minimize spatio-temporal auto-correlation a minimum time lap of five minutes between two successive locations was maintained throughout the session if the bird stayed at the same place. Time was set to zero every time a bird flew away. The habitat features at actual radio-tracking locations ("visited locations") were compared to a same number of randomly chosen locations within an individual's home range. Minimum convex polygons (MCP) were used to delineate home ranges in which random locations were generated with the program ArcView (ArcView GIS 3.3, Environmental Systems Research Institute Inc., California, USA). When generating the random locations a buffer zone of 20 m was included around the visited locations. Habitat characteristics were mapped at each location within a circle of 1 m radius (Table 1). The mapping of the random locations was always conducted within up to two days after the completion of the mapping of visited locations, in order to achieve data standardisation.

Statistical Analysis

The statistical analysis was conducted using the program "R" (R Development Core Team [2004]). To evaluate the feeding microhabitat we compared the visited with the random locations using binomial regression (Hosmer 1989, Collett 1991).

To reduce collinearity, we first checked whether habitat variables were correlated ($r > |0.7|$). Using the remaining habitat variables we defined 54 candidate models, which were composed of all combinations of the different variables. The square of the variables vegetation height and bare ground were also included in order to model possible curvilinear habitat preferences along gradients. The different levels for orchard types (apple, pear, etc.) were merged with their corresponding age structure (old, medium, young) in a first analysis. Using the best model identified thereby we then evaluated whether there was an interaction between bare ground and vegetation height and whether the levels within the habitat variables could be reduced to fewer levels. As individuals were considered a random factor, we analysed the data applying a mixed model approach (Generalized linear mixed model GLMM; procedure glmmML). This provided information about whether the foraging locations differed from the random locations averaged across all birds, thereby extracting trends in microhabitat preferences (Gillies et al. 2006). Models were ranked according to the AIC value and evaluated through their respective AIC weights (probability that the model is the best among all fitted models; Burnham et al. 1998, Johnson et al. 2004). To assess the predictive capacity of the best model, we calculated Cohen's kappa (Cohen 1960, Fielding et al. 1997).

3. Results

Of a total of 12 captured and tagged birds, seven could successfully be tracked (Table 2). Five individuals disappeared after short time, from which at least one case was predated.

The individual home range sizes (MCP) varied between 2.1 and 9.2 ha (mean ± SD = 4.8 ± 2.4 ha). Because it was not certain, whether 20 locations sufficed to get an accurate estimate of home range size, we conducted a bootstrap analysis in which the home range sizes were calculated as a function of an increasing number of randomly selected locations among the actual foraging locations (ArcView GIS 3.3, Environmental Systems Research Institute Inc., California, USA). It turned out that 16 locations were enough to get good estimates of the home range size, making our estimates reliable.

The availability of the different habitat types within the home ranges was obtained from aerial orthophotos (Swiss Topo, Bundesamt für Landestopografie, Seftigenstrasse 264, Postfach, CH-3084 Wabern). The most frequently occurring habitat type within home ranges was orchards (68.9 %), with apple accounting for 47.8%. The proportions for the other habitat types were vineyards (9.1%), vegetables (8.0%), anthropogenic habitat (6.2% [buildings and canals]), grassland (4.1%) and fallow land (3.7%) (Fig. 1).

Model selection for the microhabitat analysis revealed that eight models were in the 95% confidence set of best models (summed Akaike weights >0.95; Table 3). All of them contained the variables bare ground, habitat type and vegetation height (≥ 328.49 AIC) with the best model only containing these three factors. These variables can thus be considered to play an important role in foraging habitat selection. Some uncertainty remained in regard to the role of ant nests, herbicide and mowing regime, with the summed Akaike weights of these models being 0.451 for presence of ant nests, 0.428 for mowing regime and only 0.277 for herbicide application. This suggests that the first two factors contribute more to species occurrence at foraging locations than the latter factor. The inclusion of an interaction between bare ground and vegetation height (a scenario where wrynecks would tolerate higher vegetation when the amount of bare ground is high) did not improve the model (AIC: 343.2).

In a next step, we evaluated whether fruit sorts and age of orchard influenced habitat selection. This was first tested by fitting a model, in which fruit sort was taken into account, but not orchard age; this model performed worse (AIC: 340.9) than the best model (328.5), suggesting that fruit sort was unimportant. In contrast, the model considering orchard age but not fruit sort was close to the best model (AIC: 331.2), suggesting that age played a greater role than fruit sort. We used the latter model for estimating model parameters (Table 4).

A back transformation of these parameter estimates show that wrynecks have an optimum at locations offering about 60% of bare ground (Fig. 2). Fallow land, meadowland and orchards were the preferred foraging habitat types, whereas vineyards, gravelly soil, vegetables and anthropogenic habitat were avoided (Fig. 1.b). Within orchards, wrynecks preferred old and medium aged types whereas young orchards were avoided (Fig. 1.b). Wrynecks also preferred to forage in either low (< 10 cm) or very high (> 30 cm) vegetation; medium grass vegetation height was seemingly avoided.

The predictive capacity of the best model yielded a kappa of 0.58. According to Landis & Koch (1977) this is a moderate degree of concordance. The rather low sample size may be the reason for the only moderate fit.

4. Discussion

Although we could only radiotrack seven wrynecks this study provides decisive insights into the foraging ecology and selection of habitat types as well as microhabitat structures of this endangered species.

Wrynecks predominantly foraged in orchards with a high availability of bare ground. Although few radiolocations could be attributed to foraging activity, we are quite confident that most locations concerned hunting birds, above all because radiotracking was performed during the peak of food provisioning to nestlings, i.e. when energy demands are maximal.

Marginal habitats (trees and bushes) and fallow land were the habitat types for which the highest degree of preference was observed (ratio of proportional use on availability; Fig. 1.b). However, these habitats represent a very tiny fraction of overall availability within the seven home ranges (Fig. 1). This qualifies their importance, especially in regard to orchards, which are predominant and abundantly used. This result agrees with Freitag (1998), who also found a clear preference for orchards. These habitat selection patterns may result from ant prey abundance and/or accessibility, which both may depend on habitat type and microhabitat structure (Atkinson et al. 2004, Aschwanden et al. 2005, Buckingham et al. 2006, Ioset 2007).

Geiser et al. (in review) found the highest ant abundance in meadow (0.25 nests/m^2), orchards (0.22), riverbanks (0.21) and set asides (0.20), but only very low numbers in vineyard (0.12) and cropland (0.05). This fits nicely with the preferred foraging habitat types in this study: habitat types with high ant nest density (orchards, meadowland, riverbank, set asides [fallow land]) were preferred over habitat types with low ant nest density (vineyards, cropland or vegetables).

Access to ground-dwelling ants is certainly to large extent vegetation-dependent. Within ant-rich habitats, wrynecks tend to forage where ground vegetation cover is medium, with an optimum around 60% bare ground. The access to food is certainly easier if the vegetation cover is not too dense. The access would be easiest if there was no vegetation at all. Yet, ant density may be low at such places, since *Lasius niger*, the most dominant species in the food of the wryneck in Valais (Ehrenbold 2004) feed on aphids (Seifert 1996). On the other hand, the ants themselves may prefer habitats with sparse vegetation due to their need of sun radiation on nests for reproduction (Seifert 1996). It is not clear yet, how ant density varies with vegetation cover.

Similar results regarding bare ground have been obtained for other terrestrial insectivorous bird species (e.g. woodlark [Maurer 2006], hoopoe [Ioset 2007], common redstart [Martinez 2007]). The preference for medium sward height is less easy to interpret in terms of prey abundance and accessibility. We believe this pattern might be purely artefactual in the end. Indeed, medium vegetation height was rare at the study site because grass in orchards is mown regularly, whilst fallow land remains usually unmown for years. Moreover, the preference for semi-open vegetation cover was not influenced by the height of grass. The fact that places with full ground vegetation cover are avoided, can be easily explained by the barrier of swards, which hinder a bird's movements on the ground (Sutherland et al. 2004, Atkinson et al. 2004).

Another important feature of the foraging habitat is the presence of perches, since wrynecks rely on a perch hunting strategy to detect their ant prey (Ruge et al. 1988, Bitz et al. 1993). This tactic could be confirmed during this study: wrynecks never walk on the ground for long time, as do for example hoopoes (Ioset 2007). The dependence on perch opportunities may explain why open habitats are systematically avoided.

A preference for old and medium-aged over young orchards can in our opinion only be explained by a higher density of ant nests, since ground vegetation cover and availability of perches do not fundamentally differ with respect to age. What differs substantially, however, is the mass of foliage, which would support denser aphid populations in older fruit plantations, i.e. denser ant populations and thus more nests. An ideal foraging habitat for the wryneck would thus have a scarce ground vegetation cover, dense ant populations and numerous hunting perches such as trees.

5. Implications for conservation

The intensification of agricultural practices implies an increasing use of fertilizers, which results in denser ground vegetation cover. Wrynecks forage preferentially on half-bare ground patches, a microhabitat which has become rare in the agricultural landscape matrix in central Europe. Unless new practices develop which lead to an extensification of grassland, there is not great hope for the survival of the species in intensive farmland. The elimination of hedges and trees in homogenised matrices represents another serious obstacle as the availability of hunting perches and nesting cavities is considerably reduced.

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Table 1: List of habitat variables. Orchard estimation is based on average trunk diameter.

Group of variables	Variables	Levels	Description	Remark
I. Habitat type	Apple	Apple; young, medium, old	Young: < 5 cm	Including quinces
	Pear	Pear; young, medium, old	Medium: 5 – 15 cm	
	Apricot	Apricot; young, medium, old	Old: > 15 cm.	
	Plum	Plum; young, medium, old		
	Cherry	Cherry; young, medium, old		
	Fallow land	no		Tree/bush, forest, riverbank, thuja plantation
	Meadowland	no		Any kind of mown grassland
	Anthropogenic habitat	no		Paved street, canal, buildings
	Gravelly soil	no		Gravel, dust road
	Vegetables	no		Including strawberries
	Vineyard	no		
II. microhabitat structure	Bare ground		0 - 100%	Accuracy of 5 – 10%
	Vegetation height		0 cm 1 cm 3.5 cm 7.5 cm 15 cm 25 cm 40 cm	Continuous, but recorded categorical as 0, 0-2, 2-5, 5-10, 10-20, 20-30, >30 cm
III. Agricultural practice	State of mowing	regularly/not mown		
	Application of Herbicide	Yes/no		Whether or not an ant nest was present
IV. Ant nests	Ant nests	Present/absent		Whether or not herbicides are applied

Table 2: Details of the tagged wrynecks in Central Valais 2006, with the individual ring code, the nestbox code, time period with tag, home range size (minimum convex polygon MCP), number of recorded foraging locations, number of visited locations and reason for failure.

Ring code	Nestbox code	Ringing date	Time period with tag	MCP (ha)	Visited locations (n)	Remark
Y28720	A62[1]	29.6.	29. - 30.06.	-	3	disappeared
Y28561	A66b	14.6.	14. - 24.06.	2.10	20	
Y28565	A91	1.6.	1. - 8.06.	-	5	killed by predator?
Y28705	A103s	20.6.	20. - 29.06.	9.21	20	
Y28706	B08[1]	22.6.	22. - 23.06.	-	0	disappeared
Y25361	B31b[1]	12.7.	12. - 17.07.	5.30	20	
Y25509	B36e	8.6.	8. - 20. 06.	3.00	20	
Y19376	B38	28.6.	28.06. - 3.07.	-	4	abandoned brood
Y28656	B39e	12.6.	12. - 25.06.	3.92	20	
Y28576	C5sw	31.5.	31.05. - 8.06.	-	6	disappeared after few days
Y28738	C24ne[1]	19.7.	19. - 20.07.	3.37	20	
Y28674	DM	14.6.	14. - 24.06.	6.46	20	
Mean ± SD				4.77 ± 2.44		

[1] No activity sensor deployed.

Table 3: Model ranking for habitat selection of seven wrynecks using generalized linear mixed models. The habitat variables that were considered for each model are indicated by an x. Shown are the AIC value, dAIC (difference in AIC value in regard to best model) and the AIC weight. The models are ranked according to the AIC weight. Of the fitted 54 models, only the models with weight > 0.05 are shown. Note that the continuous variables "Bare ground" and "Vegetation height" include both the linear and the quadratic term.

Bareground	Habitat	Vegetation height	Mowing regime	Ant nests	Herbicide application	AIC	dAIC	weights
x	x	x				328.49	0	0.23
x	x	x		x		328.90	0.41	0.18
x	x	x	x			329.08	0.59	0.17
x	x	x	x	x		329.41	0.92	0.14
x	x	x			x	330.34	1.84	0.09
x	x	x		x	x	330.82	2.33	0.07
x	x	x	x		x	331.06	2.57	0.06
x	x	x	x	x	x	331.41	2.92	0.05

Tab. 4: Point estimates (on the logit scale) standard error, z-statistics and probability level for the parameters of the best "orchard age" – model. The intercept refers to habitat type "Orchard medium".

	estimate	SE	z	Pr (>|z|)
(Intercept)	1.18	0.63	1.88	0.06
Bare ground	0.07	0.02	4.02	< 0.001
Bare ground^2	0.00	0.00	-2.89	< 0.001
Habitat (Orchard old)	0.11	0.35	0.32	0.75
Habitat (Orchard young)	-1.22	0.59	-2.06	0.04
Habitat (vegetables)	-15.50	352.00	-0.04	0.97
Habitat (meadowland)	-0.78	0.57	-1.35	0.18
Habitat (anthropogenic habitat)	-2.83	1.17	-2.41	0.02
Habitat (gravelly soil)	-4.10	1.23	-3.34	< 0.001
Habitat (fallow land)	1.13	0.69	1.65	0.10
Habitat (vineyard)	-3.86	1.03	-3.74	< 0.001
Vegetation height	-0.23	0.06	-3.92	< 0.001
Vegetation height^2	0.01	0.00	4.18	< 0.001

Figure captions

Fig. 1.a: Average proportions of available (MCPs) vs. used habitat types (GLMM) in wryneck home ranges (n=7).

Fig. 1.b: Probability of occurrence of wrynecks in different habitat types. The line showing the probability of 50 %, which represents indifference towards a certain habitat type. Above 50 % a habitat is preferred, below it is avoided.

Fig. 2: Occurrence probability of wrynecks in different habitat types, compared to the frequency of available and visited locations in relation to the proportions of bare ground.

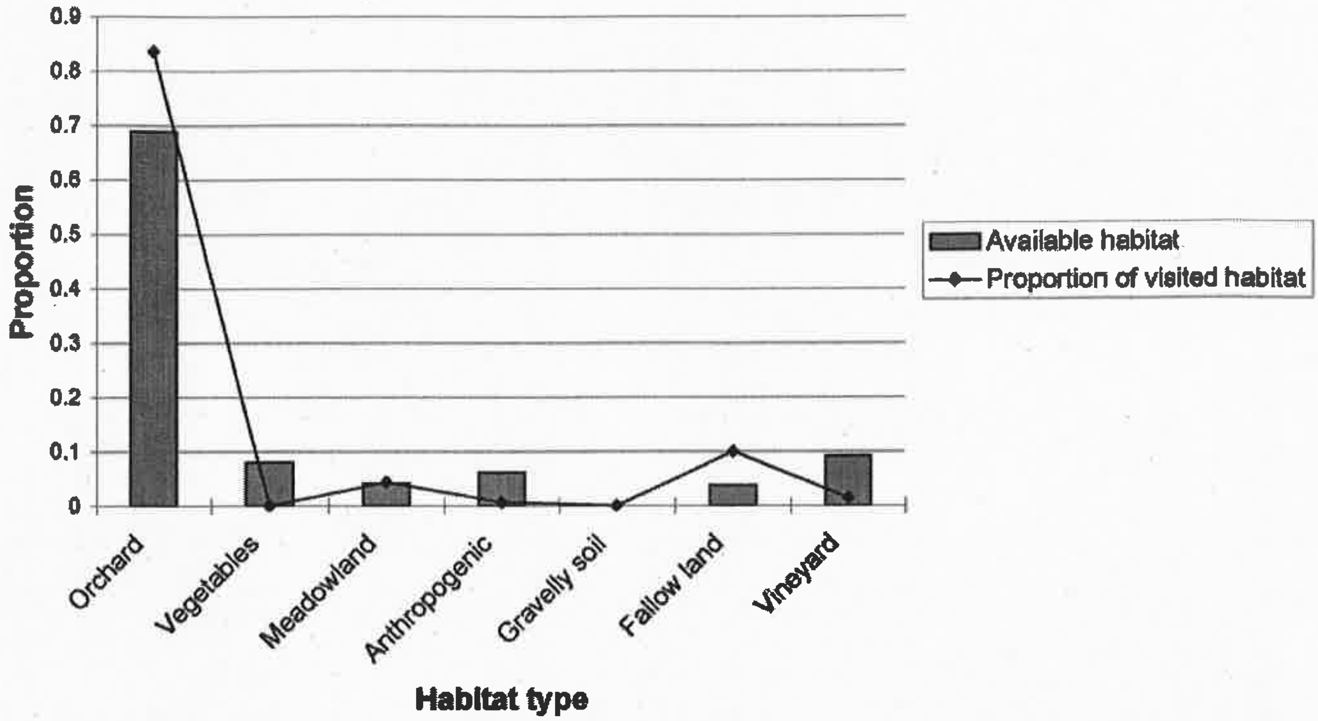

0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Proportion
Available habitat
Proportion of visited habitat
Orchard
Vegetables
Meadowland
Anthropogenic
Gravelly soil
Fallow land
Vineyard
Habitat type

Fig. 1.a

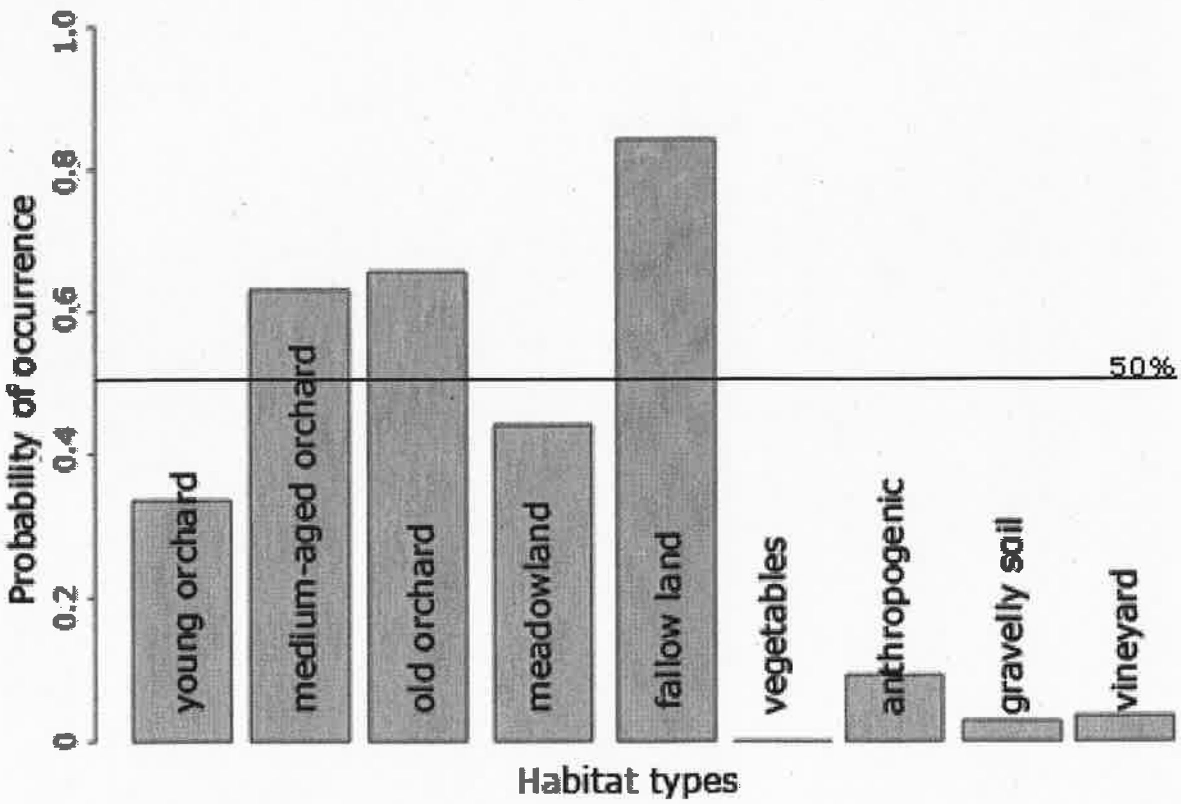
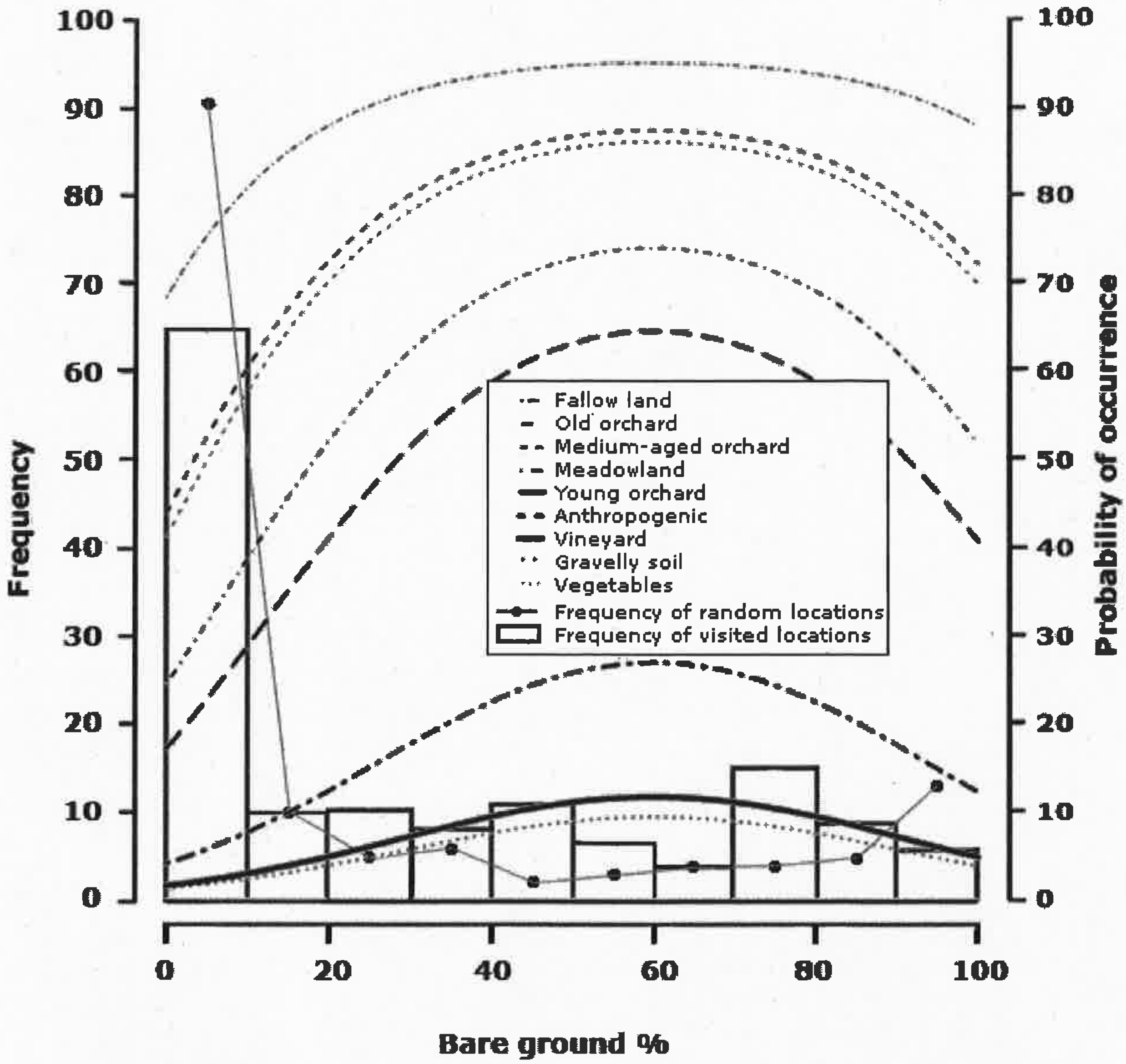

1.0
0.8
0.6
0.4
0.2
0
Probability of occurrence
50%
young orchard
medium-aged orchard
old orchard
meadowland
fallow land
vegetables
anthropogenic
gravelly soil
vineyard
Habitat types

Fig. 1.b

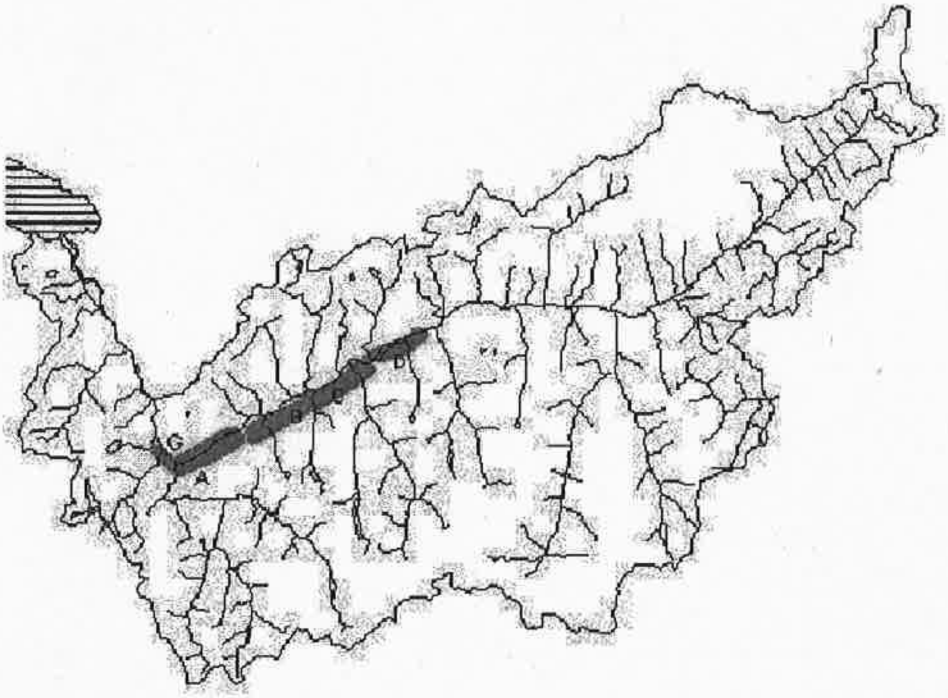


Frequency
Probability of occurrence
Bare ground %
0
10
20
30
40
50
60
70
80
90
100
Fallow land
Old orchard
Medium-aged orchard
Meadowland
Young orchard
Anthropogenic
Vineyard
Gravelly soil
Vegetables
Frequency of random locations
Frequency of visited locations

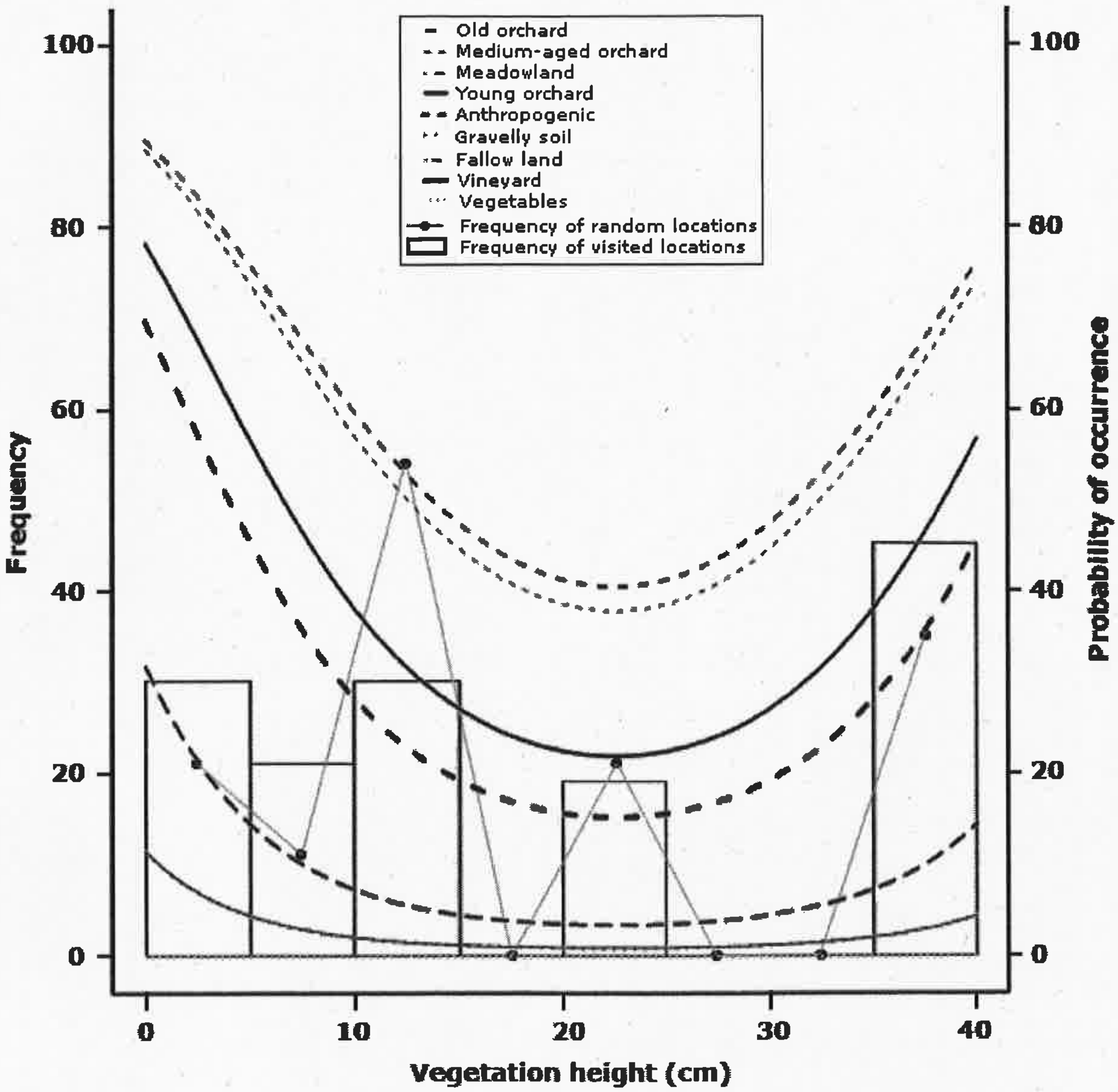
Fig.2:

Appendices

App.1: Study site (blue) with the five different zones in the Canton Valais



App. 2: Occurrence probability of wrynecks in the preferred habitat types in relation to the proportions of vegetation height, compared to the frequency of available and visited locations.

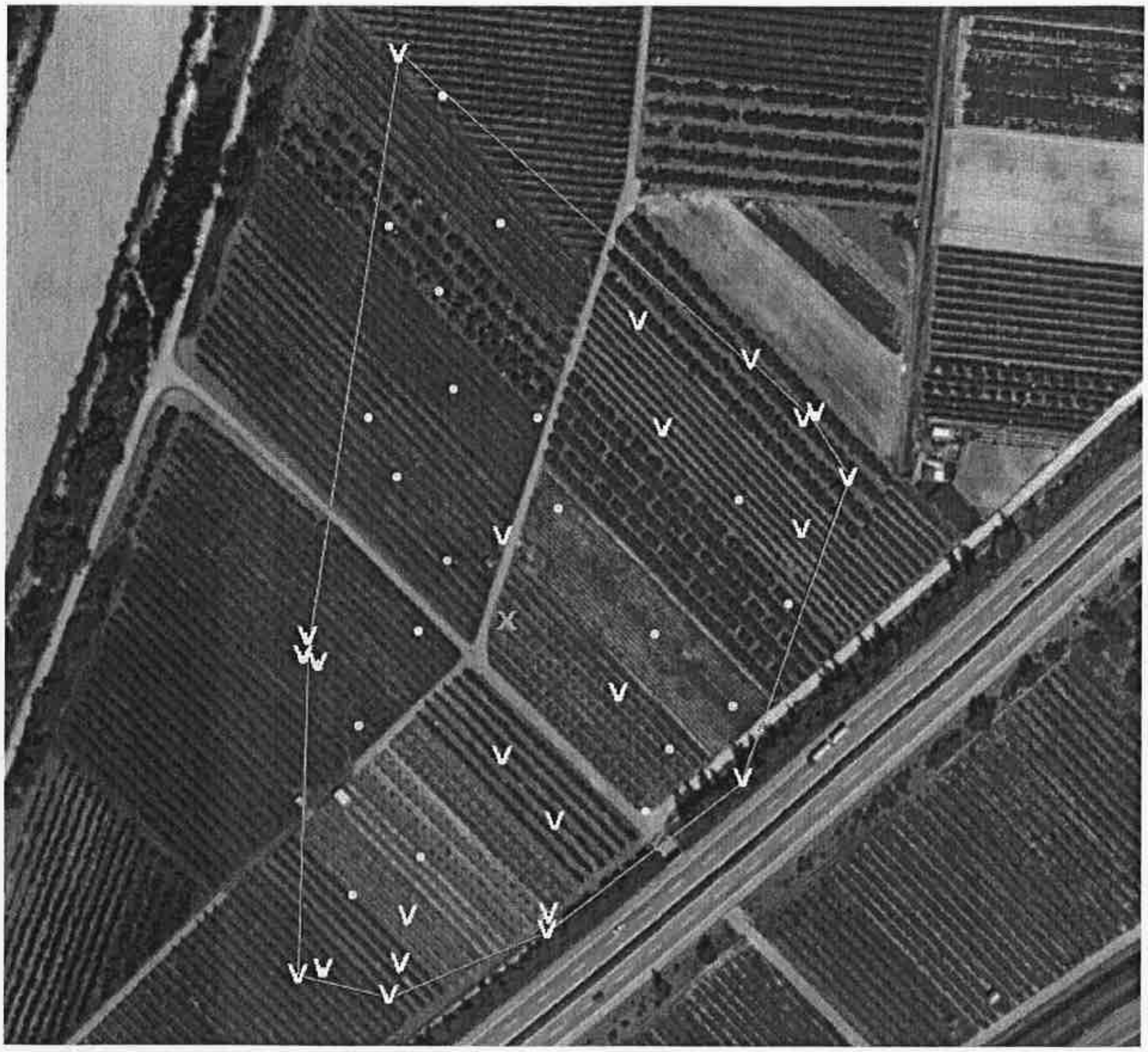


App. 3: Habitat use of individual Y28561 from nest box A66. Shown are the actual foraging locations (V), the random locations (dots), the border of the minimum convex polygon and the location of the nest box (X).

App. 4: Habitat use of individual Y28705 from nest box A103. Shown are the actual foraging locations (V), the random locations (dots), the border of the minimum convex polygon and the location of the nest box (X).

App. 5: Habitat use of individual Y25361 from nest box B31. Shown are the actual foraging locations (V), the random locations (dots), the border of the minimum convex polygon and the location of the nest box (X).

App. 7: Habitat use of individual Y28656 from nest box B39. Shown are the actual foraging locations (V), the random locations (dots), the border of the minimum convex polygon and the location of the nest box (X).



App. 8: Habitat use of individual Y28738 from nest box C24. Shown are the actual foraging locations (V), the random locations (dots), the border of the minimum convex polygon and the location of the nest box (X).

App. 9: Habitat use of individual Y28674 from nest box Dm. Shown are the actual foraging locations (V), the random locations (dots), the border of the minimum convex polygon and the location of the nest box (X).

App. 10: Calculation of minimum locations needed for representation of MCP of the seven tagged individuals (from the nestboxes A103, B31, B36, B39, C24, Dm)