

Table VI.5: Comparison of the characteristics of the true home ranges and the random areas. Significance levels of the Mann-Whitney and randomisation tests.

	Mann.-Whitney p-value	Mean of the characteristics of the 1000 random sets of 8 'home ranges'	Mean of the characteristics of the 8 true home ranges	Randomisation p-value	Confid. Interv. for p-value.
TA (ha)	0.73	18.36	18.92	0.43	0.02
NP	0.002	16.57	28.25	<0.001	<0.001
PD (n/100m ²)	0.006	102.32	211.76	<0.001	<0.001
TE (m)	0.13	3398.22	4439.52	0.13	0.01
ED (m/ha)	0.03	184.64	263.97	<0.001	<0.001

The p-value for the Mann-Whitney test: significance of the difference between the characteristics of the true home ranges and the simulated ones.

The p-value of the randomisation test: probability that, for a specific characteristic, the mean of the set of true home ranges belongs to the population of means of the 1000 random sets of 8 'home ranges'.

VI.F Discussion

The results outlined above indicate two different aspects.

Firstly, in biological terms the results of the study point towards the preference of roe deer fawns for areas close to the edge between habitat types, as was already shown for adult roe deer by Reimoser (1996) and Tufto et al. (1996). There was a clear selection for transition zones (buffers) on the second order of selection (home range versus total study area), however on the third order the results were less convincing. Because of the different compositions of the home ranges and the interaction between the second and third order of selection, no general conclusion concerning the habitat preferences could be drawn from the individual selection patterns of the fawns at the third level (bedding sites within the home range).

Whether the used areas (home range) and the individual locations (hiding places) are

chosen by the doe or by the fawn, cannot be answered from this study. According to Lent (1974) and Epsmark (1969) the fawn acts independently from the doe with regard to the spatial (but not temporal) decision in the hiding process. The decision of the fawn is anyhow only on a spatial microscale, since it is spatially limited to the home range of the doe. Linnell (1994) states that 100 % of the home range of the fawn during its first summer is situated in the home range of the doe. On average the area used by the fawn covers 35% of the doe's home range during that period. Therefore one could conclude that the doe, to give birth, selects within its home range a zone characterised by the presence of many small habitat patches or many transition zones. The fawn subsequently chooses its bedding sites within this zone, independently of the doe. A main characteristic of the bedding sites of the fawns would be to provide good hiding possibilities (Kurt 1966, Mysterud 1998). Within forest stands bedding sites are found at localities that offer greater concealment, higher ground vegetation and more canopy cover than random sites in the forest. Because of the penetration of light from open areas in the forest at the edges of the forest stand, these transition zones are characterised by a richer ground vegetation, thereby offering more hiding cover, than the more shaded areas deeper in the forest. This could, partly, explain the preference of the fawns for this transition zones.

Although bed-sites in fields offer greater concealment than those in the forest, a preference for bed-sites in forest stands is found (Linnell in press). This preference for forest patches can be seen as an anti-predator adaptation since fields offer good concealment opportunities to fawns but do not allow does to approach their fawns without being seen by predators (Byers & Byers 1983). The use of areas characterised by the presence of many patches and consequently a high density of edges (PD and

ED in our study), allows the doe to approach the fawn, using the cover provided by a forest patch, even when the fawn is lying in more open grassland or heathland vegetations. When using areas encompassing many small patches of different vegetation types, the doe and the fawn can find complementary aspects of different vegetation types at short distances. This also enables the doe, when searching for food, to stay in close proximity of the fawn. According to Linnell et al. (1998b) the doe stays, on average, within 50-200 meters of the fawn (but this can go up to 2.5 km). Fawns living in areas characterised by a lower patch density are forced to travel larger distances to fulfil their needs, and use, consequently, larger areas. Figure VI.4 shows the observed relationship between patch density and home range size.

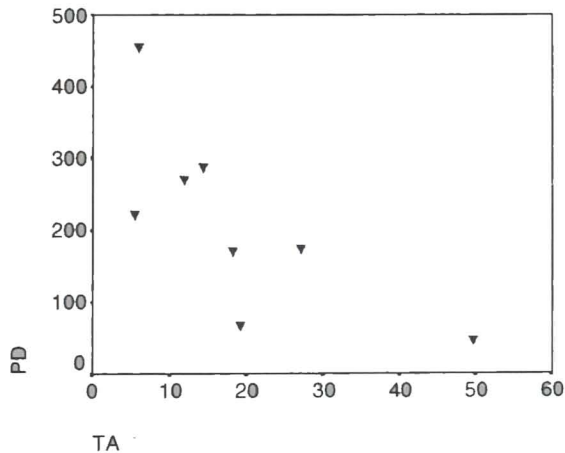


Figure VI.4: Relationship between patch density (PD, number of patches / 100m²) and the size of the 'home ranges' (total area in ha) of 8 fawns during the first months of their life.

Secondly the results show the importance of the method used to define the home range. The fact that the ratios of the HR95, CA and the percentages of the observations in the HR95 and the CA are similar for the eight animals (although there is a large variation in the size of the MCP) indicates that the animals have similar

space use patterns. Simulations with other random algorithms gave different ratios of the HR95 and the CA compared to the MCP (unpubl. data).

When evaluating the effectiveness of a method the consistency of the results can be a useful criterion. The often-used MCP was the worst method for defining the 'resource use'. Using the MCP as definition resulted twice in accepting and once in rejecting the H_0 hypothesis. The most stable results were found when using the HR95. The significance levels for rejecting the H_0 showed less variation and the rankings of preference were the same, whatever definition was used to define the available habitat. Finally, even the significance values of the preferences for the different buffer zones varied hardly when using the HR95 as definition.

Applying the MCP95, as definition for the used areas, returned the same ranking, whatever definition was applied for 'available habitat', but the individual significance of selection and avoidance differed more and there was a greater variation in the significance level for rejecting the H_0 .

Using HR95 to define resource use gave hardly any difference whether the total arbitrarily delineated study area, or the MCP of all the observations together was used, to define the available habitat. Since the MCP is a more straightforward and unambiguous method for defining the available habitats on the second order of habitat selection, we suggest that the MCP of the observations of all the animals pooled together should be used rather than a subjectively defined 'study area'.

One unexpected result was the fact that applying the sum of the individual MCP's to define the available habitat resulted each time in the rejection of the H_0 hypothesis

even when the other definitions resulted in accepting the H_0 . However, in the meantime this analysis always resulted in less significant individual values for the multiple comparisons.

The results of using Fragstats to analyse the characteristics of the eight roe deer home ranges (using both the HR95 and the MCP) confirm the findings of the compositional analysis. The analysis gives substantial evidence that there is a preference for zones characterised by high values for ED and PD, both criteria for areas rich in patches and consequently a high density of transition zones or edges. These results show that, using compositional analysis, the existing differences between home ranges and study area - resulting from the animal's habitat selection - can only be detected when biologically correct and fine tuned methods are applied as definitions for 'use and availability'.



VII General conclusions

VII.A Methodological aspects and research implications

VII.A.1 Quantifying the availability of the resources; food and cover (chapter II & chapter III)

VII.A.1.a Food

The literature review showed that, when studying roe deer diet composition over the large geographical distribution range of roe deer, the impact of the habitat the roe deer are living in exceeds the influence of the used research method on the research outcome. This makes us question the decision of Tixier and Duncan (1996) not to include the results from faecal analysis in their review, since *'the species composition of the fragments in faecal samples differs considerably from stomach samples'*.

The review also showed that, though the habitat type has the most significant impact on the diet composition, major differences can occur in diet composition between animals living within the same 'habitat type', even when situated in the same geographical region (e.g. two Polish Forests, both classified as 'mixed forest' (Siuda et al. 1969 and Gebczynska 1980)). This findings question the use in habitat selection studies of 'habitat types' being defined as mappable units of land supposed to be homogeneous with respect to vegetation and environmental factors (see also chapter III and VII.A.1.b).

Due to the influence of the habitat and of the research method used, identical research techniques must be applied and the samples for each season must be taken from animals living in the same habitat, when studying the seasonal variations in roe deer

diet. Otherwise the influence of habitat (available food resources) and applied research method, will mask seasonal changes in diet composition.

Our results clearly illustrate the importance of determining the final use of the research results and the exact research questions (changes of roe deer diet over seasons versus influence of habitat). Depending on this, the appropriate scale, both in time and space, of the measurements and research design have to be chosen (see also Doncaster et al. 1996, Litvaitis et al. 1996). This choice will determine which research methods can be used and whether or not results based on different research methods can be pooled or compared.

VII.A.1.b Cover

We successfully refined the cover pole method of Griffith and Youtie (1988). Omitting the intermediate step of summarising the concealment values of each 0.1 m into 0.5m hiding cover values, ameliorated the correlation between the hiding cover estimate and the concealment of the cardboard silhouette of a roe deer. We even achieved, contrary to Griffith and Youtie, high correlation coefficients for simulated bedded animals.

Measuring the concealment of the bedding and the standing roe deer silhouettes from three different distances clearly showed the influence of the distance chosen to take the measurements. This suggests that a pilot study should always take place to determine the distance resulting in the largest variation in hiding values, for the animal studied, in the study area. Other authors use the sighting distance (Vincent and Bideau 1982, Mysterud and Ostbye 1995, Mysterud 1996) as a measure of hiding cover, bypassing the methodological problem of defining the measuring distance. This

method, however, requires defining the object to be concealed, which is again a subjective and anthropocentric decision.

The large variation in hiding cover values in forest stands of the same forest class, made it, in our study area, impossible to translate forest classes into cover classes. This is, however, often done in habitat selection studies (e.g. Lagory 1986, Aulak and Babinska-Werka 1990, Tufto et al. 1996). In our work the forest classes were taken from the national forest cartography. Our results reveal the risk of assuming, without further testing, the existence of a direct relationship between forest stand characterisation, based on the tree layer, and the cover present in the stand. Future research should indicate which other elements (soil type, management history etc.) have to be taken into account, in order to allow the prediction of the cover present in forest stands, using available database and GIS information.

In heterogeneous forest stands, the tests revealed large differences in concealment values depending on the observation direction. Taking these differences into account to calculate the hiding cover estimate did not improve the accuracy of the cover estimate. However, both the average cover and the variation in cover, depending on the observation direction, are important in understanding why roe deer select a specific bedding site (Myserud 1998). Therefore we suggest using both cover characteristics jointly, rather than trying to integrate them into one 'cover estimate'.

The large differences in hiding cover directly influence the probability of observing roe deer in different forest stands (Vincent and Bideau 1982). Roe deer management is mostly based on population estimates or roe deer abundance indexes, both based on visual observations. Further research on the relationship between forest type, hiding

cover and the probability of observing roe deer is needed. The results have to be integrated into roe deer management tools such as distance sampling, kilometre indexes and others.

VII.A.1.c In general

Both for food and cover our results clearly illustrate the importance of understanding the impact and the constraints of the research methods used to quantify the available resources (life requisites). The results indicate that the influence of the applied methods depends on the scale and the objectives of the research.

Both for food and cover our results make us seriously doubt the validity of the assumption that 'environmental characteristics change throughout the landscape and are constant within a habitat type'. The use of 'habitat types' is very popular in habitat mapping in wildlife research and corresponds to the 'land unit' concept (Corsi et al. 2000). Cover and food values are attributed to habitat types and this information is used to study habitat type / habitat use associations. The derived relationships are used in Habitat Evaluation Procedures (Anderson and Gutzwiller 1996) to construct habitat suitability models (e.g. Van Deelen et al. 1997, Didier and Porter 1999), being part of habitat management or reintroduction programs (e.g. Donovan et al. 1987).

Rather than using geographic information systems for classifying the landscape into habitat types (simplification of the reality) and using fixed relationships to deduce the resource (life requisites) values from the habitat types, we advocate to use geographical information systems in a different way.

A first step is to study the existing relationships between the resource (hiding cover or food availability, nesting possibilities) and different other (easily mappable) environmental characteristics such as dominant vegetation type (e.g. Klötzli 1965 for

food), canopy cover, soil type, topography and management. In a second step this information can be used in a GIS to map the distribution of the main resources based on several thematic maps. As the variation in the availability of one life requisite can be independent of an other requisite this will result in different thematic maps representing the distribution of those requisites that are considered to be the most important for the species studied. This information can subsequently be used to study the influence of these environmental factors on the spatial en temporal distribution of the studied animal (Figure VII.1).

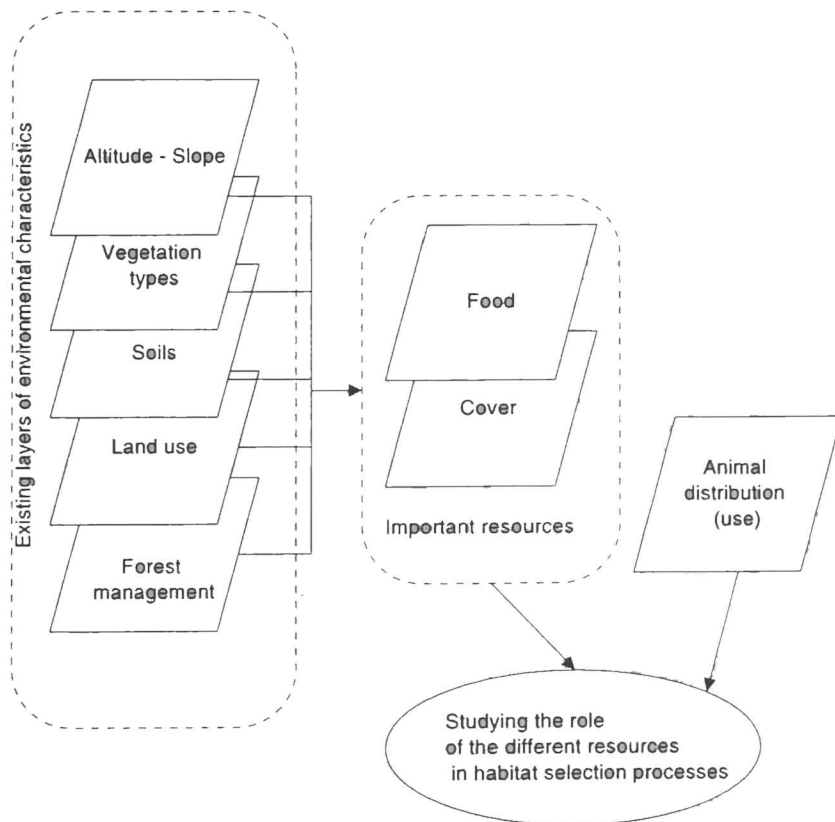


Figure VII.1: Suggested use of GIS in habitat selection studies

VII.A.2 Analysing space use to determine the resources used (chapter IV & V)

VII.A.2.a Animal fixes

The results outlined in chapter IV clearly showed that the tested GPS collar (Televilt prototype of the GPS-simplex collar) could not be used as such to study roe deer habitat use on a fine scale in temperate forest conditions. The recorded errors of the non-corrected GPS locations were too large to analyse the use of edges by roe deer. Moreover the habitat type, and the inclination angle of the collar, influenced the observation rate. The proportion of successful locations was lower under canopy cover. Also when the collar was in an inclined position the observation rate decreased. These findings coincide with the previous results of testing GPS collars for larger mammals in boreal forests (e.g. Moen et al. 1996, Edenius 1997, Merrill et al. 1998, Dussault et al. 1999, Bowman et al. 2000).

The difference in observation rate due to habitat type poses severe methodological problems in habitat use studies, since the proportion of fixes in a certain habitat type is mostly used as the measure for habitat use (Alldredge and Ratti 1986, 1992, Manly et al. 1993). The habitat-related differences in observation rate results in an over- or underestimation of the use of certain habitat types. This will consequently bias the results of habitat selection studies.

The large fluctuations in the observation rate within one habitat type cause large confidence intervals when attempting to predict the probability of a successful observation for a certain habitat type. Our results show, however, that even when using a very rough model, false conclusions concerning habitat selection due to the

habitat-related difference in observation rate can be avoided. A second possible solution would be to locate the animals more frequently (shorter intermediate time intervals) and to make use of probabilistic models to deduct the missing locations and estimate the whereabouts of the animals. Using movement vectors to analyse habitat preferences rather than animal fixes could be a third way to approach the problem (see Rempel et al. 1995). These different possible solutions must become important topics for future research in the field of radio telemetry.

Applying a linear correction method to achieve a higher accuracy, as an alternative for post-processing differential correction, was not reliable. The errors resulting from linearly correcting the raw GPS measurements vary enormously. Both an improvement and deterioration in the accuracy of the location can occur. Because of the unpredictability of the outcome when applying linear correction, we suggest using the raw, uncorrected GPS locations, whenever post-processing differential correction is not possible. Of the uncorrected locations 95 percent should, normally, be within 100 m of the true geographical locality.

Since May 2000, the Department of Defence of the United States of America has switched off the Selective Availability (SA). Until then, SA was the main error source of GPS measurements (Hurn 1989 and 1993). The fact that the SA is no longer present questions the need for post-processing differential correction. At present several researchers are focussing on the use of linear correction methods to correct for errors other than SA.

The recent evolution in GPS technology, both in hardware (active antenna) and in software (over-determination), and the fact that the SA was switched off, will speed up the possibilities of producing small, but accurate (accuracy 90% < 10 m error) GPS collars. This will finally allow the use of GPS collars to study habitat selection by medium sized and small mammals (body weight less than 30 kilos).

However, as was shown with the tested prototype GPS collar in this study, the need for elaborate benchmark tests of a GPS collar, under realistic circumstances (in the study area) will prevail (see also Dussault et al. 1999).

VII.A.2.b Deriving space use

A new method to derive space use was developed based on the idea of Dirichlet Tessellations (Wray et al. 1992a). The method allows the derivation of space use patterns directly from animal fixes, without any *a priori* assumptions about the nature of the utilisation distribution (the function that represents the space use by the species). The method is non-parametric, and is consequently (see Cresswell and Smith 1992) not influenced by the highly auto-correlated nature of fixes. There is hardly any need for defining ancillary parameters for the model, so the influence of arbitrarily chosen values is minimal. These characteristics are in strong contrast to the requirements of Kernel Distributions, the currently most frequently used method (Harris et al. 1990, Cresswell and Smith 1992, Wray et al. 1992b, Worton 1995).

The author wrote a program in ArcInfo Macro Language (AML) to analyse the animal fixes as outlined above. Since the program was written for ArcInfo this greatly facilitates overlaying animal location data with habitat information stored in the same

GIS environment. Errors and constraints resulting from the need to export the results of space use analyses from other digital environments into the GIS environment, in order to analyse habitat preferences, are thereby eliminated.

Three different similarity indexes showed the method to be a good estimator of a simulated utilisation distribution (UD). For the tested UD minimal improvements resulted from using sample sizes larger than 600 fixes. This phenomenon is probably highly dependent on the underlying (but unknown) utilisation distribution. When preparing a radio telemetric study, the number of fixes to be collected will to a much greater extent be determined by the hardware and the logistics used, and by the scientific question to be answered, than by the optimal conditions for using the chosen model. However, one should always know the basic requirements that allow the implementation of a method.

The main requirement of the method developed by the author (HR95) is that the fixes are collected using a more or less regular time schedule. This because clumped fixes (collected with an irregular observation rate) would result in delineating non-existing areas of intensive use and producing inaccurate patterns of space use. However, this is a constraint of all models that study internal home range use, as they all have to analyse the internal aggregation of animal fixes (Voight and Tinline 1980, Anderson 1982, Kenward 1987, Wray et al. 1992b).

Comparing the results of HR95 with the results of Kernel Distributions revealed that HR95 is more appropriate to delineate areas of intensive. Using derived space use patterns to delineate the 'home range' opens the discussion on how to define a home

range, if it exists (see: The home range ghost - Gautestad and Myrseth 1995 -). We started from the general, but vague, definition of a home range being 'the area used by an animal for its normal activities, during a certain period' (Burt 1943 in Kenward 2001). By stating 'normal activities', this definition automatically implies that some observations (fixes) will be regarded as resulting from exceptional movements and will not be included in the home range. Rather than omitting the fixes before calculating the home range (e.g. Voight and Tinline 1980, White and Garrot 1990) and losing biologically relevant information (De Solla et al. 1999), HR95 defines the home range as the area encompassing 95% of the volume of the total estimated space use distribution.

VII.A.3 Comparing the resources available and the resources used, in order to determine habitat preferences (chapter VI)

The fixes gathered from eight roe deer fawns during the first three months of their lives were analysed using different space use methods. The different resulting home ranges were used to define habitat use and availability on respectively second and third order of selection. The results of compositional data analyses clearly showed the influence of the used definitions on the final result and on the conclusions concerning habitat preferences (see also: Mclean et al. 1998). Applying HR95 as definition for the resources used on second order gave the most consistent results. The probability of rejecting H_0 (no habitat selection) varied more when using other methods to define the resources used. This reflects the higher sensitivity (of these methods) to the procedures used to define the available habitat. When using HR95 a higher consistency in results was also found for the internal ranking of preferences. These

results stress the importance of the definitions used as input for compositional data analysis, and confirm the high performance of the method developed (HR95).

Because of the similarity in results and the straightforwardness of the definition (not requiring any interpretation of the researcher), we recommend the use of the Minimum Convex Polygon (MCP) based on the pooled animal fixes, as definition for the available habitat on the second order of selection. Using this definition is less controversial than using the sum of the individual MCP's or using a subjectively chosen 'study area'.

When analysing the preference for transition zones on the third order of selection, only a negative selection for zones more than 45 meters from an edge was found. However, due to the interaction between second and third order of selection, a better analysis of the space use and a finer delineation of the home range, resulting in more significant results on the second order, automatically returns less significant results for the third order of selection. This was illustrated by the fact that the use of HR95 to define availability on the third order of selection never resulted in rejecting the H_0 (random use), where for the second order of selection HR95 rendered the most significant results.

These results illustrate one of the main problems of analysing habitat selection. Habitat selection is a scale dependent process, both in time and space (Bissonette 1997, Morrison et al. 1998). The biological needs of an animal change through the year and throughout its life and other criteria come into play when selecting a bedding site as when establishing a home range. Using a hierarchical multilevel approach is the classical solution to analyse this complex process (Johnson 1980). However,

animal movement decisions result from a complex of several factors acting simultaneously at different hierarchical levels. Therefore the movement influencing processes function rather over a scale continuum in time and space than over discrete levels (see Gautestad and Mysterud 1993, Litvaitis et al. 1996, Garshelis 2000). Because of the great influence of the methods chosen to define 'use' and 'availability' at an 'artificial' level of selection, and because of the interaction between the different levels of selection in the test-procedures - both aspects illustrated by our results - there is a permanent need to question the biological meaningfulness of used methods and definitions.

VII.B Biological conclusions

VII.B.1 Food selection and diet

The review on roe deer diet clearly revealed the tremendous variation in roe deer diet, linked to the habitats occupied by roe deer populations. Roe deer are found all over Europe (Linnell et al. 1998a), in habitats ranging from lowland marshes to mountain regions. This shows the flexibility of roe deer in choosing food resources. This flexibility allows roe deer to select its home range in a large variety of different habitat types (second order of habitat selection, Johnson 1980). Predicting the roe deer distribution based on the distribution of food resources is therefore hardly possible. Mysterud et al. (1999) compared the relationship between habitat selection and food availability for domestic sheep (*Ovis aries*) and roe deer. For sheep the habitat selection was highly correlated with grass availability. For roe deer however there was no correlation between the availability of herbs and habitat selection during summer. Mysterud et al. (1999) suspect that this can be due to a more complex system of habitat selection for roe deer, including trade-offs between the selection for food and

cover. Our results (see next paragraph) confirm this idea. However, the fact that Mysterud et al. only used the availability of herbs as a measure of food availability (in contrast to the large variety of plant species eaten by roe deer) could partly explain the lack of correlation found in their study.

VII.B.2 Radio telemetry, edges and cover

Both in the summer of 1997 and of 1998, four roe deer fawns were located daily. Though more fawns were radio collared only four resulted each year in similar sets of almost three months of radio tracking. Other fawns were predated or their radio collars failed. This three-month period coincides with the period that the fawns are left behind by their mother and do not flush immediately when approached by humans or predators (Linnell et al. 1998b). Though a sample size of eight is rather small, some general tendencies were observed.

Analysing their space use patterns and home ranges revealed a large variation in the size of the area used over the same period by animals of the same age class. Both classical preference analysis (using compositional data analysis), and an analysis of the used areas compared to randomly defined areas within the study area, revealed the preference of the roe deer fawns for areas characterised by many small patches of different vegetation types and consequently a large amount of edges. Fawns living in areas consisting of many small patches of different habitat types used smaller 'home ranges' than fawns living in more homogeneous parts of the study area. For adult roe deer the preference for edges and transition zones had already been shown to exist before (e.g. Reimoser 1986b, Tufto et al. 1996).

The preference for areas characterised by many small patches and a large amount of edges points to the need of roe deer for both food and cover (Reimoser and Mauser 1993, Mysterud 1998). The presence of many small patches of different vegetation types at short distances allows both fawn and mother to fulfil their needs without having to move too far from each other. The fawn mostly needs hiding cover as an anti-predator strategy during the first weeks of life (Mysterud and Østbye 1999, Linnell et al. in press), the doe needs both extra food supply - to feed the fawn - and hiding cover, to approach the fawn without revealing its hiding place (Byers and Byers 1983, Aanes and Andersen, 1996).

These results clearly show that not only the abundance but also the spatial distribution (patch sizes, distances between different habitat patches) play a key role in wildlife-habitat interactions and should therefore be integrated in habitat selection studies (see also Otis 1998). Moreover the results illustrate the importance of trade-offs between different environmental factors, acting on different spatial and temporal scales (see VII.A.3), in roe deer habitat selection processes.

VII.C Final conclusions and recommendations for future research

There is a clear need for more reliable knowledge on the interaction between roe deer populations and their environment as information base for an efficient and accurate management of the expanding roe deer populations in Europe.

The results of both our theoretical and empirical research clearly show the problems in gaining this knowledge when applying the classical methodology of comparing the use and availability of different 'habitat types'. The validity of the use and the results of this approach are jeopardised by:

- the assumption that habitat selection and habitat preference reflect the suitability or importance of environmental elements (Hobbs and Hanley 1990).
- the problem of defining the scale of the research and the selection of the appropriate research methods subsequently (chapter II & VI)
- the assumption that environmental variables are homogeneous within a 'habitat type' and change throughout the landscape (chapter II & III).
- the assumption that habitat selection is the result of a hierarchical selection process (allowing a multiscale approach (Johnson 1980)) rather than the result of different factors functioning simultaneously at different scales (chapter VI).
- the assumption of equal probability of observation of the animals, independent of their location (equally when the method used is visual observation, capturing, classical radio tracking or the use of GPS collars) (chapter III & IV)
- the use of space use models based on predefined utilisation distributions or assuming independence of the animal fixes, or models only returning the borders of the 'home range' (chapter V).
- the fact that only the abundance and not the spatial distribution (number of patches, patch sizes, distance between patches) are used in classical habitat selection methods (chapter VI).

We therefore suggest the following strategy could be implemented in the future to study the interactions between roe deer populations and their environment;

1. Quantify the relationships between different, easily mappable, habitat features (dominant vegetation, canopy closure, topography, soil type, land use and management) and the availability of food and cover or the probability of human disturbance (or other factors considered to be important).
2. Use GIS to create thematic maps providing the temporal and spatial distribution of the available resources and other environmental factors.
3. Whenever future research shows sufficient improvement in the accuracy of lightweight animal-borne GPS collars, their use will provide possibilities to follow roe deer with short intermediate time intervals, 24 hours a day, without disturbing the

animals. Use the results of pilot studies to correct for habitat-related differences in observation probability.

4. Use space use models not requiring independent animal fixes, nor the input of ancillary parameters, to derive the space use of each animal wearing a collar (or tracked by other means).

5. Overlay the thematic maps representing the distribution of the environmental factors and the derived space use of the animal. Apart from analysing the influence of the abundance of environmental characteristics on the animals space use, this approach allows to analyse the influence of the size and the distance between patches on their use by roe deer. It enables us to study the influence of each of the factors separately as well as the trade-offs between the different factors functioning at different scales.

6. Compare the differences in habitat selection and differences in population dynamic characteristics (survival and reproduction) between the different individual radio-tracked roe deer or groups of roe deer.

Using such an approach the means provided by GIS for addressing the multidimensional scale of wildlife-environment interactions could be fully utilised. We believe that applying such a methodology will better facilitate the establishment of functional relationships between environmental factors, roe deer habitat use and population dynamic characteristics, than using the classical descriptive studies documenting patterns of use (see also Gavin 1991). Aggregating the local information and relationships into models on a broader scale will result in more valid Habitat Suitability Models and better Habitat Evaluation Procedures. According to Levin (1992) we have to learn to retain the essential information from each scale level, without 'getting bogged down in unnecessary detail', allowing us to transfer knowledge between different biological scales. Finally, this should results in a better understanding of the role of environmental factors in roe deer population regulating processes.

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Glossary

This glossary contains terms and definitions frequently used in this work. Words marked in bold are referring to a term of this glossary. The most important reference works for this list are Bookhout (1996), Boitani and Fuller (2000) and Kenward (2001).

2D-locations: a **GPS** observation based on three satellites, resulting in latitude and longitude co-ordinates.

3D-locations: a **GPS** observation based on four (or more) satellites, resulting in altitude, latitude and longitude co-ordinates.

Animal fix: place where an animal was observed or located.

Auto-correlation: an index of the spatiotemporal relatedness in a set of locations

Automated radiotelemetry: telemetry based on the principle of one or more fixed, automated stations receiving the information transmitted from the animal, or locating the animal.

Availability (of a resource): a measure for habitat, food or other resource within an area on a map or a home range.

Compositional analysis: a method to analyse data in proportions (typical for habitats) that avoids the unit-sum-constraint and any assumption that observations are statistically independent.

Culling: Shooting animals

DCA: **Detrended correspondence analysis:** ordination method frequently used in vegetation analysis.

DOP: **Dilution of Precision:** a measure of the degradation of the precision of a **GPS** location. The **DOP** computation is based on the geometry of the satellites being used.

Edge density: total edge length (e.g. within the outlines of a home range) divided by the area.

GPS: **Global Positioning System.** System initiated by the United States Department of Defence. Based on 24 orbiting Navstar Satellites, continuously broadcasting radio signals, **GPS** receivers on the ground can calculate their longitude, latitude and altitude.

GPS rover: **GPS** receiver used to collect **GPS** observations in the field.

Habitat Evaluation procedures (HEP): procedures used by wildlife management organisations and government bodies to assess the impact of possible habitat management or to evaluate the feasibility of wildlife programs. **HEP** are often based on **Habitat Suitability Indexes**.

Habitat Suitability Index models (HSI): models based on attributing, for the species studied, a suitability index value (ranging from 0 to 1) for a set of (key) environmental characteristics (cover, food, nesting possibilities) to each habitat type discerned. Subsequently a 'overall' habitat suitability index is calculated for each habitat type (using a mathematical formula combining the different HSI-values).

Habitat type: a mappable unit of land that is assumed to be 'homogeneous' with respect to vegetation and environmental characteristics.

Home range: an area repeatedly traversed by an animal.

Homing: the process of deliberately approaching an animal while **radio tracking**.

HR95: a home range based on 95% of the volume of the TIN - estimated UD.

Kernel functions: mathematical functions of distances of **locations** from a point that provide an index of location density.

Linear correction method: a correction method used to improve the accuracy of a **GPS** location. The method uses a second GPS receiver, of which the geographic co-ordinates are known to estimate the 'positional error'. This information is used to recalculate the locations collected by a **GPS rover**, after downloading the information from the rover.

Location: the estimated x and y (and z) co-ordinates of an animal (or another object).

Manual radiotelemetry: radio telemetry based on the principle that the researcher locates (by **triangulation** or **homing**) the animal equipped with a radio transmitter.

MCP: Minimum Convex Polygon: a polygon in which the linkage distances between the peripheral locations sum to a minimum.

MCP95: The MCP based on 95% of the locations, after removing the 5% most extreme outliers.

Non-parametric space use (home range) models: techniques (models), used to derive the space use from a **radio-tracked** animal, that do not attempt to parameterise the assumed underlying **utilisation distribution**.

Parametric space use (or home range) models: techniques (models), used to derive the space use from a **radio-tracked** animal, based on the estimation of parameters of the probabilistic function that describes the underlying **utilisation distribution**.

Patch density: number of different **habitat type patches** divided by the area.

- Post-processing differential correction:** eliminating part of the errors of a GPS observations gathered by a GPS rover, using information gathered by a base station (GPS receiver of which the geographic co-ordinates are known). The correction is done after retrieving the GPS locations from the rover. Contrary to the **linear correction method** the correction is done using the estimated 'time error' and not the 'positional error'.
- Radio tracking:** locating an animal equipped with a radio transmitter.
- Satellite telemetry:** telemetry based on the process of transmitting the information and / or locating the animal using satellites e.g. ARGOS.
- Second order of habitat selection:** the selection that determines the composition of the home range within the landscape.
- Selective Availability:** Intentional degradation of the Global Positioning Signal by the Department of Defence of the United States of America. Switched off (temporarily) in May 2000.
- Third order of habitat selection:** the selection determined as the relative use of habitats within the home range.
- TIN:** Triangulated Irregular Network
- Triangulation:** locating an animal by determining the direction of the strongest radio signal from at least three different observation-locations.
- Twinspan:** Two-way indicator species analysis: a common method for community classification in vegetation analysis.
- Utilisation Distribution:** a distribution representing the (relative) use of different geographical positions by the animal studied.

PUBLICATIONS

I Articles in international reviewed journals

- Cornelis, J., Casaer, J. and Hermy, M. 1999. Impact of habitat and research techniques on Roe deer diet: a review. *Journal of Zoology London* 248: 195-207
- Casaer, J., Hermy, M., Coppin, P. and Verhagen, R. 1999. Analysing space use patterns by thiessen polygon and triangulated network interpolation: a non-parametric method for processing animal fixes. *International Journal of Geographic Information Science* 13: 499-511.
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II Papers at international conferences and symposia

II.a) Published in full in proceedings

- Casaer, J., Hermy, M., Verhagen, R. and Coppin, P. 1997. Habitat use analysis using thiessen polygon and triangulated irregular network interpolation. Proceedings of the XIV ISOB Meeting, Marburg, Germany (Tectum Verlag 1998).

II.b) not published or available only as abstract

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V Articles in or parts of books

- Casaer, J. Exploitatie van de natuur; Jacht. 2001. In: Kuijken et al. 2001. *Natuurrapport 2001. Toestand van de natuur in Vlaanderen: cijfers voor het beleid. Mededeling van het Instituut voor Natuurbehoud nr. 18: 114 – 115*
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III Papers at other conferences and meetings

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