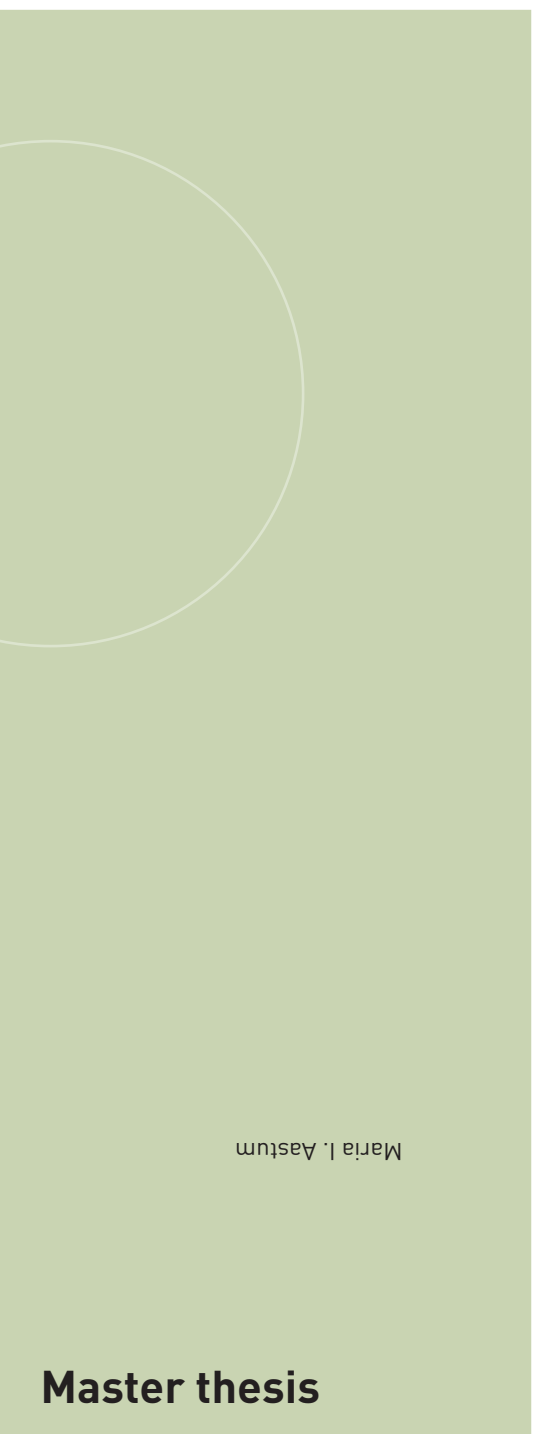


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## **Forage selection by cattle in heterogeneous pastures in Nicaragua**

Master Thesis in Natural Resource Management  
Department of Biology

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**Preface**

This study was carried out as a part of the PACA (Pastures in Central America) project, a cooperation between Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Norwegian Institute for Nature Research (NINA) and Norwegian University of Life Sciences (UMB). The overall goal of the project is to build the regional capacity to support livestock farmers in Central America to manage diverse forage resources with the aim to enhance cattle production and reduce pasture degradation. The project runs simultaneously in Honduras, Guatemala and Nicaragua.

This thesis was written according to Ecography's author guidelines.

## Abstract

Cattle's selective grazing in heterogeneous pastures in Muy Muy, Nicaragua were studied between October 2004 and January 2005. Three paddock types differing in soil nutrient content and grazing pressure were studied, i.e. nutrient poor (NP) paddocks with high and low grazing pressure, and nutrient rich (NR) paddocks with low grazing pressure. In each paddock the floristic composition of Diets, Cow transects and Control transects were measured, and the proportion of each species in the Diet and in the transects was calculated. Additionally, an index of selectivity (IS) was calculated from this data.

In the NP paddocks the cows were grazing selectively in two spatial scales, i.e. the floristic composition of the feeding sites was substantially different from the floristic composition of the overall paddock. Also, the composition of the diet differed from the composition of the feeding sites. However, my results indicate that other factors than dietary preferences were affecting the choice of feeding sites. Further, the decision to eat a species was not dependent on the relative abundance of more preferred species, but the proportion of a species in the diet increased as the availability of the species in consideration increased. As hypothesized, in the nutrient rich paddocks the cows were grazing more selectively than in the nutrient poor paddocks, due to more abundant and nutrient rich forage species in these paddocks. The only preferred species in the NR paddocks was the relatively nutrient rich grass *Panicum maximum*, and this species was also the most abundant one in the NR paddocks.

This study indicates that the cows in the nutrient poor paddocks were not excessively selective in their choice of forage, probably due to low abundance of preferred species, and relatively high abundance of species of low forage quality. Further, the utilization of the paddocks are probably not the most advantageous, as a relatively large proportion of the species were avoided in both the diet and the feeding sites, and quite few species were selected in both. Moreover, it is indicated that cows prefer relatively short vegetation in their feeding sites, whereas taller species such as shrubs and vines will be avoided. Some of these shrubs and vines, however, are selected in the diet. An alternative management practice therefore might be to keep most of the vegetation short by removing species that are avoided in the diet leaving plants of preferred shrub- and vine species, scattered around in shorter vegetation, as a supplement to grass as forage.

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## Introduction

Large herbivores make foraging decisions hierarchically, in scales from region, landscape, plant community, foraging path and, plant-to-plant module taken in the single bite (Senft et al. 1987, Pastor et al. 1997, Skarpe et al. 2000). According to optimal foraging theory (Pyke et al. 1977, Belovsky 1986, Stephens and Krebs 1986, Illius and Gordon 1993) a foraging animal makes the following four, often interdependent, decisions: 1) which patch type to visit, 2) how long to stay in each patch, 3) which food types to eat in the patch and 4) which foraging path to employ in the patch (Moen et al. 1997). This theory defines the optimal diet as the one that maximises the net intake rate of energy or mass (Westoby 1974, Belovsky 1978).

Optimal foraging theory thus predicts that the animal will first consume food items with the highest ratio of food value to time and energy spent in searching for and handling the food item. The animal will always seek the highest ranked foods available, and when the food items of the highest rank are depleted, foods will be added on to the diet in their rank order (Pyke et al. 1977). The decision to consume less preferred species depends on the availability of preferred species (Pyke et al. 1977, O'Reagain and Mentis 1989) and selecting good quality forage is, in most cases, more important to the animal than consuming greater amounts of forage (Bailey 1995, Moen et al. 1997, Skarpe et al. 2000). It has been observed (O'Reagain and Mentis 1989) that the least preferred/most avoided species are not added on to cattle's diet even when nearly 100% of the tufts of the preferred species have been grazed. The cattle probably choose to regrazed the tufts of the preferred species rather than adding a low quality food item to their diet. Some avoided species may be detrimental or poisonous for herbivores (Crawley 1983).

Free-ranging animals are expected to select forage at all spatial scales, but even in fenced grazing systems, if the paddocks are relatively large and the animal density is low enough, the animals interact with landscape systems by selecting plant communities and other landscape components for feeding. Animals' relative preference for plant communities is generally a linear function of the relative abundance and/or nutrient quality of the preferred plants in the community (Senft et al. 1987).

Through diet selection and foraging behaviour large herbivores seek to obtain maximal quality and adequate quantity of food. It has been shown that moose (*Alces alces*), which selected high quality foraging locations and food items, increased their survival and reproductive success (Moen et al. 1997).

Grazing animals compose their diets by differentiating between plant species and plant parts that vary in nutritional value and in chemical and mechanical defences (Provenza and Balph 1988). Morphological characteristics, such as spines and thorns, often affect the foraging behaviour of grazing animals (Cooper and Owen-Smith 1986) as well as content of various deterring compounds (Cooper and Owen-Smith 1985). Likewise, grazing animals mainly select biomass with high proportion of leaves and low proportion of stem, as leaves have higher nutritive value. Thus they will largely reject tall, mature pasture (Cowan 1985).

Nevertheless, it should be kept in mind that generalists herbivores, such as cattle, are not foraging as selectively when they are hungry as when they are satiated, i.e. grazing preferences are not fully expressed when supply of valuable forage is low (Crawley 1983).

Particularly in relatively resource poor environments, grazing often affects vegetation composition so that the proportion of unpalatable species increases (Sparrow et al. 2003). In such environments, plants species are usually slow growing, nutrient poor and contains high levels of quantitative defences (Coley et al. 1985). In more resource rich environments, plants may instead minimise negative effects of herbivory on fitness by tolerance traits, including fast compensatory growth (McNaughton 1984, Coley et al. 1985), and such fast growing plants are often nutrient rich with low content of quantitative defence compounds (Coley et al. 1985). Selectively grazing animals can modify the structure of plant communities, and this is normally a result of altered interspecific plant competitive hierarchies (Crawley 1983). In the absence of grazing one plant species may dominate another less competitive species. However, if grazing animals selectively consume this dominating species, the less preferred species may become the stronger competitor and actually become dominant over time. On the other hand, if the animals prefer the less competitive species, this species may disappear totally from that area (Crawley 1983). In semi-arid environments it has been observed that species diversity is highest at low grazing pressure, and as the pressure increases, the abundance of dominant grasses increases, whereas the

abundance of forbs decreases (Milchunas et al. 1988). If the high grazing pressure continues, the pastures productivity of forage species might decline and the species composition might change in favour of woody plants, grasses and weeds unsuitable as forage (Crawley 1983). Both grazing pressure and nutrient availability are manageable in a livestock situation by controlling stocking rate and by applying fertilizers, provided the economic situation allows. A better understanding of the effects of grazing pressure and nutrient availability on species diversity and on the vegetation's forage quality could thus be of large value in pasture management.

The possibility for livestock to select the best grazing available in different seasons and situations will probably increase animal productivity (Taylor 1986), survival and condition. Since defoliation cause a lag in growth until tillers can develop new leaves, also the temporal variation in grazing pressure on the different species and individuals enhances survival and production of the species and the sustainability of the pasture (Caldwell and Richards 1986).

Selective grazing has the potential to alter the pastures' floristic composition. Knowledge about the capacity of livestock to graze selectively in relatively heterogeneous pastures is important for a better understanding of the potential to consume forage of above average value, in addition to knowledge about the possible effects of grazing on the pasture vegetation.

The primary objectives of this study were (1) to determine if cattle in heterogeneous pastures are grazing selectively at different spatial scales, and (2) to find out if cattle in paddocks managed extensively and presumably with a low abundance of preferred species are less selective than in paddocks with lower grazing pressure and a high proportion of preferred species. Further, I wanted (3) to find out whether the decision to eat a food is independent of its abundance, but depends on the relative abundance of more preferred foods, and (4) to test if the cattle in paddocks with nutrient rich soil, where forage was assumed to be more abundant and nutrient rich, were grazing more selectively compared to the cattle grazing in paddocks with nutrient poor soil.

## Materials and Methods

### Study area

The study area, Muy Muy, is situated in the South of the department of Matagalpa in the North-central region of Nicaragua between the geographical coordinates  $85^{\circ}30'$  and  $85^{\circ}45'$  east and between  $12^{\circ}40'$  and  $12^{\circ}50'$  north. (Fig. 1)

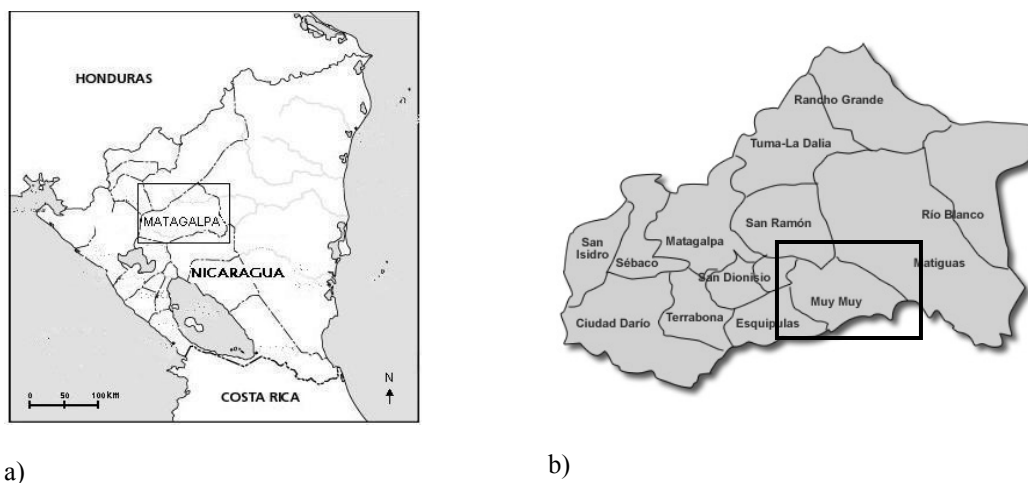


Figure 1: a) Map of Nicaragua (Vernooy and Ashby 1999) and (b) map of Matagalpa district. The study area is indicated by the box (INIFOM 2006).

### Climate

The climate is semi-arid, with an average precipitation of 800-1600 mm/year and pronounced seasonality. Rainfall is concentrated from May to November (Holmann 2001). Average temperature is  $24.0^{\circ}\text{C}$  (Vernooy and Ashby 1999).

### Topography and soil

The landscape is hilly with peaks of 1000 to 1500 m above sea level, and valley floors at about 350 m above sea level (Vernooy and Ashby 1999). Soils are mainly of volcanic origin, and are generally nutrient poor. The top horizon is prone to sheet erosion. Also, the soils have a relatively high content of clay, which causes contractions and expansions of the soil due to the presence or absence of moisture. The parent material is relatively shallow (Arauz cited in Bach Fenger 2005).

The key problems of soil fertility and soil quality in the region are low availability of soil organic matter and phosphorus for soil micro organisms. This problem is magnified by a low percentage



of fungi, probably reducing the ability of soil to provide nutrients for vascular plant growth. (Joergensen and Castillo 2001).

Along the river Rio Grande de Matagalpa are areas with soils of alluvial origin, and most of these are relatively nutrient rich (Arauz cited in Bach Fenger 2005). Under the hurricane Mitch in 1998 the pastures along the river received even more sediments. This area is the most fertile in the area; the soil is quite porous, and its content of phosphorus is fairly high (CATIE 2002).

#### Vegetation and land use

The Muy Muy area would naturally have sub-humid tropical forest in transition between the humid and dry zone. Due to clearing for agriculture, the vegetation in the area is relatively sparse, i.e. only 4% of the area's land is secondary forest (CATIE 2002). In these relatively small, remaining areas of forest, one can find trees such as *Cordia alliodora* and *Calycohyllum candidissimum*. (INIFOM 2006).

Land use is characterised by small family farms, use of monoculture pastures and low diversification of farm products. Corn and beans are the most important crops in the region, and farmers practice slash and burn of secondary forest for crop cultivation (CATIE 2002). The main economic activity in the region is dual-purpose cattle used in meat and milk production (Vernooy and Ashby 1999, Holmann 2001), and pastures cover more than 75 % the agricultural land in the community (CATIE 2002). Dual-purpose systems are generally based on grazing and hand-milking of cows with the calf at foot. The range of cattle genotypes employed is very large, combining genes from many zebu (*Bos indicus*) and European (*Bos taurus*) breeds (Jarvis 1990). Approximately 52 % of the farms have 6 to 10 paddocks, and 38 % of these are between 3 to 6 ha. The mean stocking rate in the area is 1.08 animals ha<sup>-1</sup>. Cattle are undernourished, and only 30 % of the farmers manage to provide the cattle basic nutritional requirements. Nutritional deficiency is more severe in the dry season, which results in overgrazing of pastures and heavy soil erosion (CATIE 2002). To maintain or increase animal production the pasture area are further expanded. Management of the pastures includes moderate grazing pressure and regular rotation of milking cows in addition to paddocks heavier grazed, often permanently, by young stock and dry cows. (CATIE 2002).

In Central America pasture degradation is a considerable problem (CATIE 2002). Degradation of grazing land is commonly described in terms of loss of palatable perennial plants, invasion of unpalatable plant species and soil erosion (USDA, Soil Conservation Service 1976). In most of the Central American pastures, cultivated grasses of African origin are introduced, and these grass species are well adapted to herbivory and are highly productive (Lascano and Euclides 1996). However, these grass species become less valuable as forage over time as a result of soil nutrient deficiency. Loss of grass productivity and weed invasion are often observed (Oldeman 1994). A consequence of the pastures' lower productivity is further land use pressure due to pasture expansion (CATIE 2002). This pasture expansion, in most cases, means loss of tropical forest (Szott 2000), and in Muy Muy the annual conversion rates of secondary forest to pastures are about 1%. The pasture degradation is a result of, among other factors, exceeding the pastures carrying capacity for cattle and inadequate management of pasture species and soil (CATIE 2002).

#### Data collection

The study on forage selection by cattle was carried out between October 28<sup>th</sup> 2004 and January 19<sup>th</sup> 2005. Most of the study took place in the beginning of the dry season. During the first three weeks the study area received quite heavy showers almost every afternoon, so the soil contained some water and the vegetation stayed green. As the dry season progressed, there were still some showers, and the soil did not start to dry up until the first weeks of January. As a consequence forage was relatively abundant during the study period.

Data were collected in three paddock types differing in soil nutrient availability and grazing pressure, i.e., nutrient poor low and medium high slopes with high grazing pressure of dry cows and young stock (Nutrient Poor-High grazing pressure (NP-H)), Nutrient Poor low and medium high slopes with low grazing pressure of milking cows (Nutrient Poor - Low grazing pressure (NP-L)) and nutrient rich alluvial flood plains with relatively low grazing pressure of milking cows (Nutrient Rich - Low grazing pressure (NR-L)). Within these paddock types 22 paddocks were studied, 8 in NP-L, 7 in NP-H and 7 in NR-L (Appendix 1).

The floristic composition of Control transects, Cow transects and cow Diets, were measured within each paddock. Control transects gave an estimate of the floristic composition of the vegetation available to the cows in the whole paddock; the Cow transects estimated the floristic composition of the vegetation available to the grazing cow in the selected feeding sites, and the Diet measurements estimated the proportion of the different species consumed by the cows. In paddocks smaller than 7 hectares (ha), 5 Control transects were sampled, and in paddocks larger than 7 ha 10 transects were sampled, and in each paddock the same number of cows were observed foraging, leading to the equal number of Cow transects. The Control transects' starting points were distributed as evenly as possible in the paddocks. From these points the measuring tape was laid out northward in straight, 50 m long lines (Fig. 2 a). On the measuring tape, at every 1.5 m, a cross of sticks (1 m x 1 m) was placed, giving four points; one at each end of the cross (Fig. 2 b). The plants which touched the points were registered. Only one plant of each species was registered at each point. Nevertheless, several species were normally registered at each point. Dead plant material and tree saplings taller than 1.5 m were not registered. From these registrations the proportion of each registered species was estimated by dividing the number of registrations of the species in consideration by the total number of registrations in that transect.

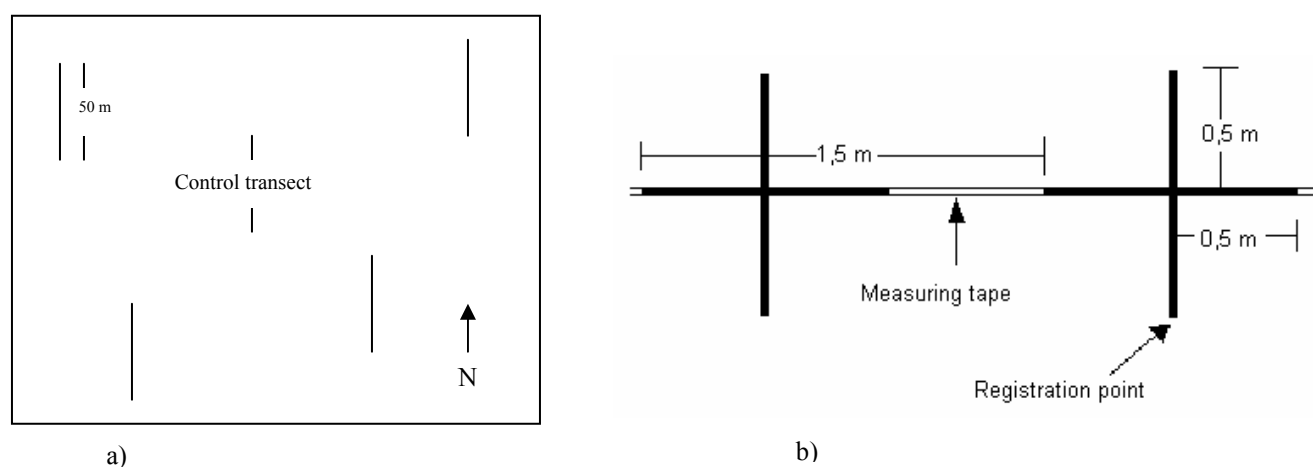


Figure 2:

- a) Within each paddock Control transects were laid out northwards in 50 m long straight lines. In paddocks smaller than 7 ha 5 transects were sampled, whereas 10 were sampled in paddocks larger than 7 ha.
- b) On the measuring tape a cross of stick was placed, giving four registration points every 1.5 m. The plants touching the points were registered, and from these registrations the proportion of the species in the paddock were estimated by dividing the number of registrations of the species in consideration by the total number of registrations in that transect. The Cow transects, which gave an estimate of the proportion of the different species available to the cows, were sampled in a similar way.

The floristic composition of the Diet was measured by following and observing the foraging cows. At arrival in the paddock the cows required a few minutes to get accustomed to our presence, and as soon as they were grazing undisturbed, a mature cow was selected to be observed. Binoculars were most often used while observing the cows, as the cows seemed to feel more relaxed when they were observed from a greater distance. Each plant or plant part consumed was registered using a small tape recorder, and only one plant/plant part of each species was registered in each bite. The observation was completed after ten minutes of recording, or when the cow had walked 50 m. Occasionally, the cow walked 50 m in less than 5 minutes, and then we assumed the foraging had been disturbed, possibly because of our presence, and the observation was rejected. We also rejected the observation if the foraging was seriously interrupted, i.e. if the cow lay down or stopped eating for some other reason, and we had been observing her for less than 5 minutes. The floristic composition of the Diet was calculated as the number of bites of the species in consideration divided by the total number of bites in that observation. While the cow was being observed, a field assistant laid out a measuring tape along the cow's foraging path, i.e. the Cow transect, and after the observation was completed the Cow transect was sampled using the exact same procedure as for the Control transect (Fig. 2 b). Each animal was only observed once.

In both the Control and the Cow transects the number of trees taller than 1.5 m, which's canopies were overhead the transect line, were registered.

To estimate the most frequently consumed species in NP and NR, the sum of all bites (in all paddocks) of the species in consideration was divided by the total number of bites, and this gave the proportion of each species in the Diet.

The species nomenclature is according to Missouri Botanical Garden's VAScular Tropicos nomenclatural database (2005). The species were classified according to their growth forms. These growth forms are graminoids (grass and grass-like monocotyledonous plants); vines (twining/climbing plants); forbs (vascular plants without significant woody tissue above or at the ground); shrubs (perennial, multi-stemmed woody plants that are usually less than 4 to 5 meters);

trees (perennial, woody plant with a single stem (trunk), normally greater than 4 to 5 meters in height. The classification is according to United States Department of Agriculture (USDA 2005).

Data handling and statistical methods

I registered presence of vascular plants in 22 paddocks, which were nested within the three paddock types, i.e. eight NP-L, seven NP-H and seven NR-L paddocks. In total I sampled 150 Control transects and 150 Cow transects, and 150 cows were observed foraging – 55 in NP-L paddocks, 55 in NP-H and 40 in NR-L paddocks. This gave a total of 450 transect and Diet estimates. The raw data was transformed into proportion data.

The experiment corresponded to an unbalanced, split plot design with paddocks nested within paddock type ( $O(B)$ ) (22 levels) as main plots, individual transects and Diets (samples) ( $P$ ) (450 levels) as split plots, paddock type ( $B$ ) (3 levels, NP-L, NP-H and NR-L) as main plot factor and Diet/Transect type ( $T$ ) (3 levels, Control transect, Cow transect and Diet) as split plot factor. The paddock type ( $B$ ) and Diet/Transect factor ( $T$ ) were orthogonal factors. The Diet/Transect factor ( $T$ ) was also orthogonal with paddocks ( $O(B)$ ). Samples ( $P$ ) were nested within combinations of  $BTO$ . Paddock and sample were treated as random factors, while paddock type and  $T$  were fixed factors. In order to test for variation in floristic composition among  $T$  and among the paddock types, the species abundance data were analyzed by multifactorial, non metric multivariate analysis of variance (Anderson 2001, McArdle and Anderson 2001) according to the following model:

$$Y_{ijkln} = \mu_i + B_{ij} + T_{i,k} + BT_{i,jk} + O(B)_{i,l(j)} + O(B)T_{i,kl(j)} + P(BTO)_{i,n(jkl)} \quad (1)$$

where  $Y_{ijkln}$  was the abundance of species  $i$  in sample  $n$  of Diet/Transect type  $k$  in paddock  $l$  of paddock type  $j$ . Parentheses indicate nesting, and symbols for two factors in combination represent interaction effects.

For the MANOVA analyses the computer program DISTLM v.5 (Anderson 2004) was used. These analyses were based on design matrices incorporating dummy variables representing nested factors as well as main- and interaction effects of orthogonal factors constructed by the

program XMATRIX (Anderson 2003). First, the full model (1) was analysed using Chi-square distances to measure differences among measurements of floristic composition, and then an analysis was run based on Euclidian distances. Error mean squares used as denominators in the different test statistics are listed in Appendix 2. Permutation tests for all sources of variation were performed, and for each test 499 permutations were used. Residuals under a full model were permuted in all permutation tests. In addition to the permutation P-value, a so called Monte Carlo P-value from a Monte Carlo sample from the theoretical asymptotic distribution of the test statistic was obtained (cf. Anderson and Robinson 2003).

An interaction between the paddock type ( $B$ ) and the Diet/Transect factor ( $T$ ) was found, and consequently the dataset was split in two, one data set consisting of all the NP data, and one set consisting of the NR data. The NP data was analysed in order to test for differences between the two paddock types NP-L and NP-H according to model (1).

The NR data were further analysed according to the following model:

$$Y_{i,jkn} = \mu_i + T_{i,j} + O_{i,k} + TO_{i,jk} + P(TO)_{i,n(jk)} \quad (2)$$

where  $Y_{i,jkn}$  is the abundance of species  $i$  in sample  $n$  of Diet/Transect type  $j$  in paddock  $k$ .

*A priori* determined contrasts between Control and Cow transects, and Cow transects and Diet were constructed for both the Nutrient Poor and the Nutrient Rich area in order to test the hypothesis that cows selected forage at different spatial scales.

The computer program CANOCO 4.5 (ter Braak and Šmilauer 2002) was used to present the major features of significant multivariate effects in ordination diagrams. Redundancy analyses (RDA) with default settings were used.

The cows' preference for the different species was measured in terms of an index of selectivity (IS), which was calculated as:

$$\text{Selection index (SI)} = \log_2 \frac{\text{Proportion of species A in Diet} + 0.01}{\text{Proportion of species A in Cow transect} + 0.01} \quad (3)$$

As an example; when the proportion of a species is equal in the Diet and the Cow transect, IS = 0, and when the proportion in the Diet is twice as high as in the Cow transect IS = 1. Thus, index values above zero indicate positive selection/preference and values below zero indicate avoidance. The selection index was calculated for two spatial scales; the selection for feeding sites and the individual cow's selection for the different species. The former was calculated by dividing the proportion of a species in the Cow transects by the proportion in the Control transects, and this index value was calculated as a mean value for each paddock.

In order to statistically test whether the proportion of a species in the Diet was dependent of the relative abundance of more preferred species in the Cow transect, i.e. any species with a calculated IS above that of the species in consideration, the data was analysed by logit regression according to the following model:

$$Y' = b_0 + b_1x_1 + b_2x_2 \quad (4)$$

where  $Y'$  is the logit transformed proportion in the Diet,  $x_1$  is the proportion of the species in the Cow transect, and  $x_2$  is the proportion of more preferred species in the Cow transect. Binomial errors were assumed. Significance was evaluated by a deviance test comparing model (4) with a model with  $x_1$  as the only explanatory variable.