The effect of vegetation type and mowing on the hunting success of male Montagu's Harriers in east Groningen, the Netherlands

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Introduction

Until the 19th century the Montagu’s Harrier *Circus pygargus* was a common breeding bird in the Netherlands with an estimated minimum of 500 breeding pairs (Zijlstra & Hustings 1992). Around that time there was a wide choice in breeding and hunting habitats: heaths, moor, wet hayland, swamps and other uncultivated land. With the disappearance of breeding- and hunting-habitats, caused by cultivation of wild-land and the intensification of agriculture, the number of breeding pairs had declined to only four breeding-pairs in 1987 (Koks *et al.* 2001).

In 1992 the EU decided that part of the agricultural land was to be set-aside as part of a reform in the Common Agricultural Policy, known as the McSharry reform (European Commission 1998). In the Netherlands a large part of this set-aside land was situated in east Groningen, an agricultural area where 20 % of the total surface (ca 10,000 ha) was laid fallow or sown with grass-seed (Koks & Van Scharenburg 1997; Aukes 2000). This caused an increase of the Common Vole (*Microtus arvalis*) population as well as an increase in the number of breeding-pairs of agricultural birds. The high prey densities attracted many raptors, including Montagu’s Harriers (Koks 1992; Zijlstra & Hustings 1992; Koks & Van Scharenburg 1997) and the number of breeding pairs of Montagu’s Harriers increased and stabilised at about 35 breeding pairs in the Netherlands from 1992 onwards, 25-30 of which breed in east Groningen (Koks *et al.* 2005).

Despite stabilisation, the population in east Groningen is still relatively small and depends on good nesting sites. And besides nesting habitat the population also needs adequate food supply in order to be maintained in the long term (Newton 1979). Knowing where Montagu’s Harriers find their food exactly in east Groningen will aid in both conservation and understanding of the birds. In this study we explore the hunting behaviour of male Montagu’s Harriers.

Harriers are diurnal ground nesting raptors that usually breed and hunt in open habitat like marshes, steppes and grasslands, aided by their sound hearing (Simmons 2000). Montagu’s Harriers typically occupy dryer areas where they prey on small mammals, birds, lizards, insects and frogs, depending on the geographic area (see Arroyo 1997). For the population in east Groningen the bulk of the diet consists of voles, followed by passerines and lagomorphs (Trierweiler 2004, Koks *et al.* 2005).

The aim of this study is to establish the effect of different vegetation types on hunting success of individual males using radio telemetry. In addition, we studied the effect of mowing of vegetation on hunting success. We chose to track males because male Montagu’s Harriers are known to supply the majority of the food to the female and young during the breeding season, as well as catering for themselves (Clarke 1996).

Methods

Study area and data collection

The study was conducted in the Oldambt, an agricultural area specialised in winter grains (*Triticum* spp. and *Hordeum* spp.) in the east part of Groningen, the Netherlands (N 53°, E 7°). The study was conducted in 2003 (June 17 till August 4) and 2004 (May 19 till August 31).

Data was collected by following four male Montagu's Harriers fitted with radio transmitters (Advanced Telemetry Systems Inc. type 4570, weight 4.7g). This device was glued onto the basis of the quills and stabilised with thread. The birds were tracked by two observers in a car for approximately eight hours a day, using an ATS Inc. Fieldmaster FM-100 receiver and an ATS Inc. 3 element folding Yagi antenna. When the bird was in sight, behaviour was scored every full minute. Recorded activities were: 1: bird out of sight; 2: flying; 3: hunting; 4: sitting, usually on pole or ground, including plucking prey and preening; 5: circling, flying without moving wing and 6: interaction with another species (not including hunting). In addition, all strikes (attempts to catch prey) were noted, discriminating between successful attempts (prey caught), unsuccessful attempts (no prey caught) and attempts with an unknown outcome (for instance if a bird was not visible for a while after making a strike).

The type of vegetation the bird occupied and the status of mowing (where appropriate) of the plot were also noted. Vegetation type was divided into 10 groups: unknown, grass (meadows with or without cattle, grassland, dykes), grass seed, set-aside (fallow land, uncultivated land, fauna strips), lucerne, grain (wheat, barley and oat), sugar beets, rough edges (of ditches and woods, roadsides, tracks), rape, other (potatoes, maize, woods, caraway, berry plantation). Mowing status was noted as the number of days after mowing (the day of mowing being day zero).

In addition to using the data collected from the four males, observations were made in 2004 at individual plots of crop (chiefly lucerne) with known mowing status by one observer sitting next to a plot and scoring any hunting behaviour of unmarked males on nearby plots in the same manner as for the radio tagged birds, including noting mowing status and vegetation. Observed non-hunting behaviour was not noted. These data were used to analyse the amount of hunting time spent and the number of prey caught relative to the amount of time spent observing.

Data Analyses

From the data all minutes spent hunting and all strikes were selected. Strikes made in minutes not spent hunting were divided among empty hunting minutes in the same day with corresponding vegetation type and mowing status. When no appropriate hunting minutes were available we created new hunting minutes for excess strikes to prevent loss of strike data. This accounted for 11 extra hunting minutes on top of 4140 hunting minutes observed.

Strike data allowed us to calculate three hunting parameters, entered as binary data. Hunting yield (the amount of prey caught per hour spent hunting) being either a prey caught (successful strike) or no prey caught (no strike, unsuccessful strike or strike with unknown outcome). Strike frequency (the amount of strikes made per hour spent hunting) being either a strike attempt or no strike attempt. Strike success (the number of successful strikes in proportion to the total number of strikes with a known outcome) being either a successful strike or an unsuccessful strike. Strikes with unknown outcome and minutes without a strike were not included in the strike success analysis.

In theory hunting yield is the product of strike frequency and strike success, except that strikes with an unknown outcome were not included in strike success analysis and hunting yield analyis. Therefore hunting yield is a minimum estimate of the actual hunting yield and strike success analysis assumes the same distribution of strikes with known outcome among strikes with unknown outcome.

Using these data, two models were created to test the effects of date, vegetation type and mowing status on all three hunting parameters. We used MLwiN 2.0 to create a three level logistic regression model which accounts for the nested structure of the data (Hox 1995, Maas & Snijders 2003). The three levels used in each model were: minute, observation day and individual, with minute being the lowest level and individual the highest level. All models tested yield, strike frequency and strike success as dependent variables. The vegetation categories ‘unknown’ and ‘other’ were left out of all analyses because of the limited relevance of these data.

Model A tested the dependent variables against date and vegetation type. This model used data collected from all four tracked birds.

Model B tested the dependent variables against date, vegetation type and mowing status. Mowing status was defined as either unmown, mown zero days ago, mown 1-2 days ago or mown 3-8 days ago. This model used only precise data collected in 2004 from both tracked birds.

The models were tested using a backward elimination method. Where vegetation had a significant effect in model A, differences between vegetation types were analysed using all available data in a binary logistic regression model in SPSS 12.0.1 correcting for individual, date and vegetation.

The extra observations of unmarked males were used to calculate observed hunting minutes and observed yield in relation to total observation time spent at different plots. Data allowed us to calculate three hunting parameters, entered as binary data. *Hunting time* (the number of minutes spent hunting per hour observed) was scored as an observation minute either with or without a hunting male. *Hunting yield* (the amount of prey caught per hour spent hunting) was scored as a minute spent hunting either with or without a prey caught, observation minutes without hunting time were not included in the analysis. *Observation yield* (the number of prey caught per hour observed) was scored as an observation minute either with or without a prey caught. These parameters were tested using SPSS 12.01 software in a binary logistic regression model using a backward elimination method based on the Wald statistic. Parameters were tested against date, plot number, vegetation type (either lucerne, grass or set-aside) and mowing status. Mowing status was divided into four categories, being either unmown, mown zero days ago, mown 1-2 days ago or mown 3-12 days ago.

Results

The final models A and B are presented in table 1a and b. Model A shows that both hunting yield and strike frequency are significantly influenced by date and vegetation type. Strike success is only significantly influenced by date. Figure 1 shows the effect of different vegetation types on hunting yield. The binary logistic regression analysis of differences between vegetation types for hunting yield showed a significant effect of date (*B* = 0.013, *Wald* = 15.314, *df* = 1, *p* = 0.000), individual (*Wald* = 41.574, *df* = 4, *p* = 0.000) and vegetation type (*Wald* = 66.673, *df* = 11, *p* = 0.000). The analysis for strike frequency showed a significant effect of date (*B* = 0.005, *Wald* = 4.793, *df* = 1, *p* = 0.029), individual (*Wald* = 50.560, *df* = 4, *p* = 0.000) and vegetation type (*Wald* = 141.443, *df* = 11, *p* = 0.000). The differences of vegetation types in their effect on hunting yield and strike frequency are presented in table 2. Model B shows that hunting yield and strike frequency are significantly influenced by vegetation type and mowing status, whereas strike success is not influenced by these factors. Hunting yield increases as the age of a mown plot increases. It is expected that mowing of vegetation is followed by a rise in hunting yield, as more prey become available. This peak in hunting yield is expected to decline as prey adapts their behaviour to the new situation (eg. by dispersing or remaining underground for longer periods). The unexpected trend is largely caused by the effect of grass seed (one plot in particular) on hunting yield, so another analysis which did not include grass seed was made (table 1c). This time no significant effect of mowing status on any of the hunting parameters is shown, though effects of vegetation types are still significant for hunting yield and strike frequency. Strike success remains unaffected by any of the factors incorporated in the model.

Plot observations

Hunting time was significantly influenced by differences between plots (*Wald* = 99.045, *df* = 17, *p* = 0.000) and mowing status (*Wald* = 125.713, *df* = 3, *p* = 0.000). Only plots mown 0 days ago significantly differed from unmown plots (*B* = 1.741, *Wald* = 86.324, *df* = 1, *p* = 0.000). *Hunting yield* was influenced by differences between plots (*Wald* = 20.756, *df* = 12, *p* = 0.054) and significantly influenced by mowing status (*Wald* = 8.105, *df* = 3, *p* = 0.044). Within mowing status, only plots mown 3-12 days ago differed significantly from unmown plots (*B* = -3.476, *Wald* = 4.407, *df* = 1, *p* = 0.036). Based on the outcome of this model, we calculated the expected hunting yield for each mow status category using the formula: $P = \frac{1}{1 + e^{-(constant + B \cdot x)}}$

The constant being given by the binary logistic regression model. The expected hunting yield is shown in figure 2. This figure shows a higher yield for males hunting on plots that are mown on the same day, followed by a fast decline of the hunting yield on later days.

Observation yield was significantly influenced by mowing status (*Wald* = 13.799, *df* = 3, *p* = 0.003), where plots mown 0 and 1-2 days ago significantly differed from unmown plots (*B* = 1.229, *Wald* = 8.340, *df* = 1, *p* = 0.004 and *B* = 1.173, *Wald* = 6.589, *df* = 1, *p* = 0.010 respectively) (figure 3).

Discussion

Differences between vegetation types had a significant effect on hunting yield and strike frequency in all models. Of the different vegetation types lucerne, grass seed and set aside offer the best hunting yield and strike frequency, followed by rape, grass and rough. Grain provides a hunting yield and strike fequency which are highly significantly lower than any of these vegetation types, though the birds still spend 21.6% (N = 3756 minutes of total hunting time) of their hunting behaviour on grains. Considering however that 42.7% (CBS 2003) of the arable land is covered with grains it is evident that male montagu's harriers tend to avoid grains, indeed, most of the hunting data collected consisted of swift hunting over grain on the way to better hunting grounds, and hunting on the stubbles left after harvesting. Hunting on sugar beets gives the lowest hunting yield and strike frequency, which is significant for all vegetation types except grain. This explains the relatively low amount of hunting time spent on sugar beets (2.5% of N = 3756 minutes). These results are not entirely consisted with those presented in figure 1, as the model shown in table 2 also uses the data collected from unmarked males, which increases the amount of available hunting data on mainly (mown) lucerne, and this model also corrects for date and individual effects.

Model A shows a significant positive trend in hunting yield, strike frequency and strike success during the breeding season. This can be caused by a higher prey abundance later in the season, as vole populations steadily increase in size towards late summer (Newton

1979). However, another explanation is that the availibility of accessible prey increases due to increased mowing efforts by farmers later in the season.

Mowing is an important phenomenon for Montagu’s Harriers in east Groningen. In many cases discovery of a freshly mowed field by a bird resulted in repeated visits there during the day. In model B inclusion of mowing status in the analysis strengthened the effect of vegetation on hunting yield and strike frequency, and cancelled the effect of date on hunting yield and strike frequency. This effect disappeared with the removal of grass seed from the analysis, but another analyses was made where mowing was classified as either mown or unmow, and mowing of vegetation had a significant effect on hunting yield ($\chi^2 = 8.257$, B = 0.526, df = 1, p = 0.00406, N = 3169) and on strike success ($\chi^2 = 12.004$, B = 0.564, df = 1, p = 0.000531, N = 671). Since mowing of vegetation is a seasonal activity increase in hunting yield and vegetation during the season might be explained through increase in availability of mowed plots.

Plot obervations

Observations on mown plots showed that male montagu's harriers spend significantly more time hunting on plots that are mown on the same day. There were no significant effects of vegetation. But since we found no significant differences between lucerne, set-aside and grass in other analyses (table 2), and since data on set aside and grass plots was very limited, this was not sursprising. Also, since there were only a few grass and set aside plots, any differences between vegetation types would likely be seen as differences between plots.

Strike success seems to be a variable uninfluenced by factors which may affect prey availability. Strike frequency and hunting yield on the other hand are influenced by such factors. It may be that Montagu’s Harriers only attempt to catch a prey when they have succesfully located one, and are succesful in 50.8% of the time (N = 713). Though strike success may differ slightly between vegetation types, and can be influenced by mowing, these effects are not significant in our most accurate models.

Of the different vegetation types Though mowing and harvesting positively affected hunting yield and strike success in all these vegetation types, the high vegetation height and density of lucern and rape meant these were especially favoured when mown and harvested. Normally hunting done on high and/or thick vegetation (like lucerne and rape) consists of bird hunting, which provides a significantly lower strike success than mammal hunting in other harrier species (Toland 1986, Simmons 2000) and other raptor species (Temeles 1985). Mowing of these vegetation types makes resident mammal prey accessible, explaining increased hunting success.

Though mowing and harvesting are important and inevitable phenomena in an agricultural setting, and a more even distribution of mowing efforts may increase the overall habitat quality for Montagu's Harriers. Because mowing efforts are typically clustered the harriers are generally more attracted by vegetation types which also offer a good food supply in an unmown condition. Looking at the total number of prey caught by the four radio tagged males on different vegetation types (figure 4) shows that most of the prey comes from set-aside land and other grassy vegetations, as well as grain, which still covers the majority of the arable land in east Groningen.

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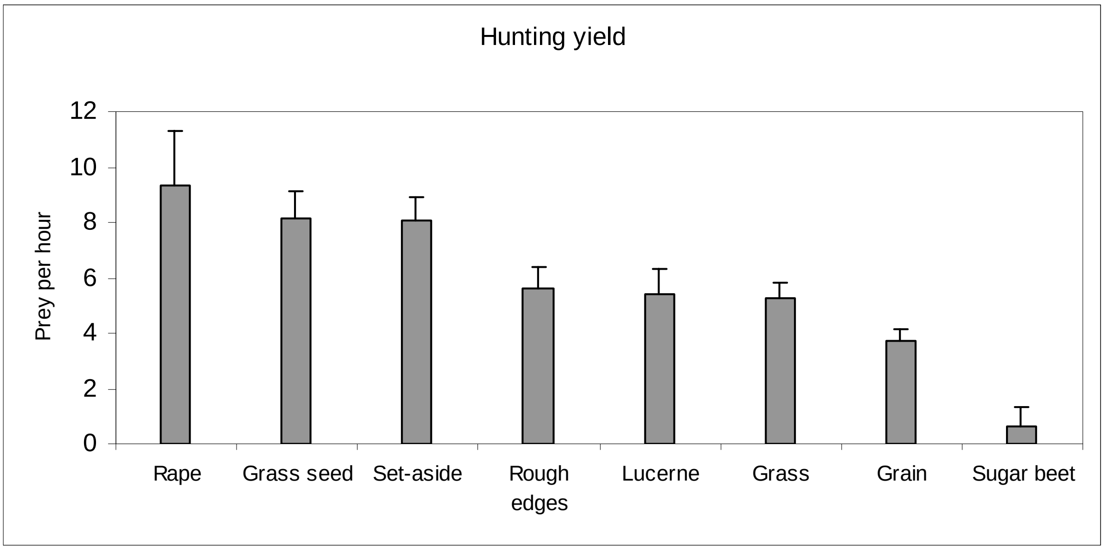

Figure 1: Average hunting yield on eight vegetation types

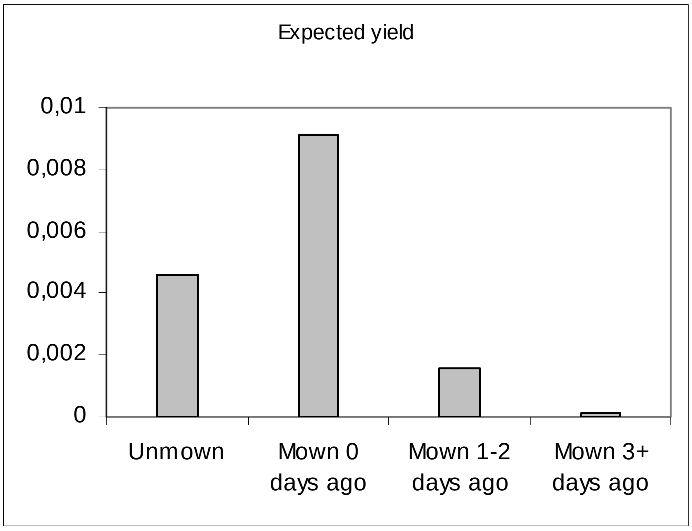

Figure 2: Expected hunting yield for unmarked males hunting on mown and unmown plots.

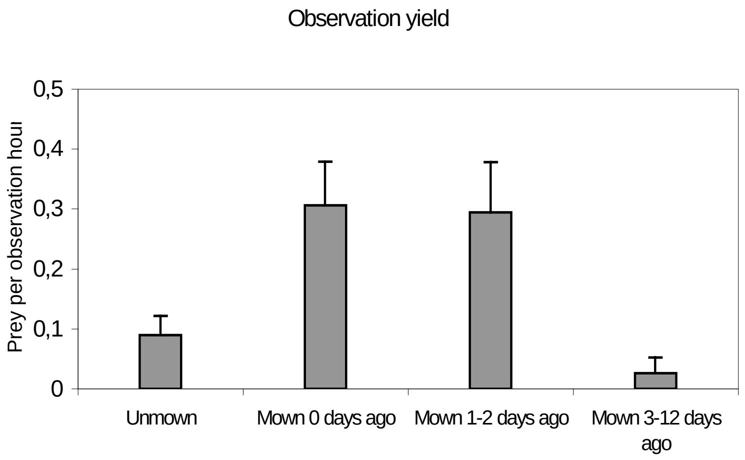

Figure 3: The number of prey caught by unmarked males per hour observing mown and unmown plots.

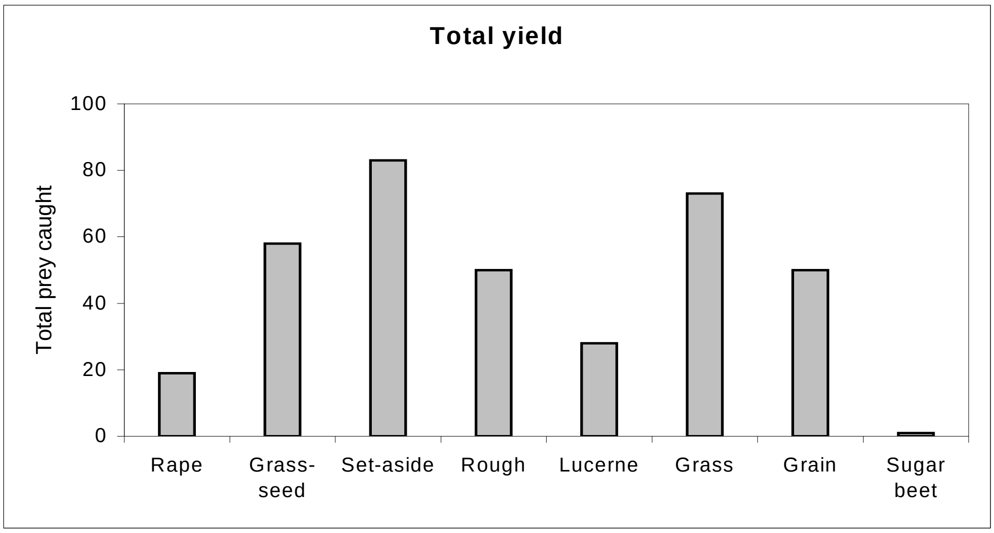

Figure 4: The total numer of prey caught on different vegetation types by the four radio tagged males.

ucerne								
rass	-0,280	1,808	1	0,179				
rain	-1,173	25,590	1	0,000	-0,893	21,070	1	0,000

			Hunting Yield				Strike frequency				Strike success			
			X^2	B	df	p	X^2	B	df	p	X^2	B	df	p
(a)	Model A													
	Fixed factors	Date	8,569	0,019	1	0,003	4,449	0,012	1	0,035	8,525	0,020	1	0,004
		Vegetation type	29,745		7	0,000	60,532		7	0,000				
	Not in model	Vegetation type									11,848		7	0,106
	N =		3756				3756				708			
(b)	Model B													
	Fixed factors	Vegetation type	23,359		6	0,001	68,483		6	0,000				
		Mowing status	13,157		3	0,004	20,841		3	0,000				
	Not in model	Date	0,842		1	0,359	0,144		1	0,704	0,002		1	0,964
		Vegetation type									0,009		6	1,000
		Mowing status									0,004		3	1,000
	N =		1960				1960				509			
(c)	Model C (without Grass seed)													
	Fixed factors	Vegetation type	23,503		5	0,000	68,541		5	0,000				
	Not in model	Date	1,226		1	0,268	0,002		1	0,964	1,208		1	0,272
		Vegetation type									4,745		5	0,448
		Mowing status	5,670		3	0,129	7,529		3	0,057	5,235		3	0,155
	N =		1735				1735				377			

Table 1: Effects of date, vegetation type and mowing status on hunting yield, strike frequency and strike success. (a) shows the model with date and vegetation type as fixed factors. (b) and (c) show the models with date, vegetation type and mowing status as fixed factors. Models A and B used all available data from the four radio-tagged males, model C used the same data as model B, but with grass-seed excluded from the analysis.

(a)	Hunting yield		Rape				Grass seed				Set-aside				Rough		
		B	Wald	df	sig	B	Wald	df	sig	B	Wald	df	sig	B	Wald	df	sig
	Grass seed	0,031	0,011	1	0,915												
	Set-aside	0,007	0,001	1	0,979	-0,024	0,016	1	0,898								
	Rough	-0,431	2,157	1	0,142	-0,462	4,629	1	0,031	-0,438	5,385	1	0,020				
	Lucerne	0,123	0,155	1	0,694	0,092	0,154	1	0,694	0,116	0,313	1	0,576	0,554	5,435	1	0,020
	Grass	-0,157	0,308	1	0,579	-0,188	0,929	1	0,335	-0,164	0,957	1	0,328	0,274	1,940	1	0,164
	Grain	-1,050	13,080	1	0,000	-1,081	27,317	1	0,000	-1,057	33,465	1	0,000	-0,619	8,478	1	0,004
	Sugar Beet	-2,928	7,986	1	0,005	-2,959	8,487	1	0,004	-2,935	8,433	1	0,004	-2,497	6,031	1	0,014

			Lucerne				Grass				Grain		
		B	Wald	df	sig	B	Wald	df	sig	B	Wald	df	sig
	Grass seed												
	Set-aside												
	Rough												
	Lucerne												
	Grass	-0,280	1,808	1	0,179								
	Grain	-1,173	25,590	1	0,000	-0,893	21,070	1	0,000				
	Sugar Beet	-3,051	8,966	1	0,003	-2,771	7,487	1	0,006	-1,878	3,422	1	0,064

(b)	Strike Frequency		Rape				Grass seed				Set-aside				Rough		
		B	WALD	df	sig	B	WALD	df	sig	B	WALD	df	sig	B	WALD	df	sig
	Grass seed	0,305	1,636	1	0,201												
	Set-aside	0,408	3,331	1	0,068	0,104	0,531	1	0,466								
	Rough	-0,131	0,308	1	0,579	-0,436	7,266	1	0,007	-0,539	15,161	1	0,000				
	Lucerne	0,145	0,332	1	0,564	-0,159	0,803	1	0,370	-0,263	2,840	1	0,092	0,276	2,493	1	0,114
	Grass	0,036	0,025	1	0,875	-0,269	3,330	1	0,068	-0,372	9,123	1	0,003	0,167	1,382	1	0,240
	Grain	-0,818	12,398	1	0,000	-1,123	53,186	1	0,000	-1,226	86,496	1	0,000	-0,687	20,384	1	0,000
	Sugar Beet	-0,848	5,483	1	0,019	-1,152	13,225	1	0,000	-1,256	16,791	1	0,000	-0,717	5,136	1	0,023

			Lucerne				Grass				Grain		
		B	WALD	df	sig	B	WALD	df	sig	B	WALD	df	sig
	Grass seed												
	Set-aside												
	Rough												
	Lucerne												
	Grass	-0,109	0,500	1	0,480								
	Grain	-0,963	32,583	1	0,000	-0,854	37,858	1	0,000				
	Sugar Beet	-0,993	9,572	1	0,002	-0,884	8,156	1	0,004	-0,030	0,009	1	0,924

Table 2: Differences in hunting yield (table 2a) and strike frequency (table 2b) between different vegetation types. All data from the four radio-tagged males and from observations of unmarked males were used.