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An in-depth look at *Dama dama*:

Characteristics of growing deer fawns and their habitats



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Abstract

In order to better understand population dynamics of an ungulate species, knowledge of specific details of the species is essential. Especially important, though less often investigated, are conditions during the first stages in life, including fawn mortality, growth, habitat, and natal dispersal. In this study, all of these factors were studied in fallow deer fawns (*Dama dama*) within the Koberg estate in southwestern Sweden. In addition, anti-predation behaviors were observed during the first few weeks of life. During the summer seasons (June-August) of 2008, 2009 and 2010, 82 fawns were caught, measured, marked, assessed behaviorally, and fitted with VHF or GPS collars. In those years, as well as the following two, observations were made regarding the continued locations of the growing fawns. The primary goals of my research efforts were to examine how anti-predator responses in fawns are expressed through their behavior and habitat choices, as well as to determine dispersal rates in the population and how they varied with changes in age and sex. Additionally, mortality and growth rates of the fawns were assessed. Another important task was to attempt to strengthen the assumptions that behavioral traits can help to signify age. Growth rates in this population within the first twenty days of life were not notably affected by sex, but by age; older fawns experienced faster growth. For habitat choice, we found that the fawns preferred a mixture of arable land and coniferous forests. Additionally, in comparison with adult females after fawning, habitat choices were strikingly similar. Dispersal distances for the fawns peaked for both females and males at the 12 and 24 month points. Finally, behavioral traits were strongly correlated with physical traits and estimated ages. This study provides a unique in-depth look at the neonatal stage in deer fawns, with regards to growth and mortality rates, habitat preferences, and anti-predation behavior.

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Introduction

The fate of an animal relies on a complex combination of factors starting at the very beginning of life. The interplay of different facets regarding sex, behavior (both innate and learned), growth, physical characteristics, and many other attributes can shape the life of the individual who possesses them. Conditions during growth, especially weather, resource availability, and population density, have been estimated to have a strong influence on adult quality of large herbivores, likely being responsible for up to 55% of the variation (Hamel et al., 2009). This implies that early growth and development is exceedingly important. Given this relationship, it is important, when trying to better understand population dynamics of a species, to put some of the focus towards the first stages in life.

The neonate stage for ungulates has been shown to be dangerous, with mortalities of those living in temperate zones averaging 47% (Linnell et al. 1995). Sex has not been shown to be a factor in fawn mortality rates (Long et al. 1998). Caughley (1966) found a pattern in the mortality curves of several mammalian species, which includes a mortality rate that begins high, drops quickly, and then exponentially increases again after a length of time at which the death rate is relatively low. Although there can be many reasons for this pattern, depending on the species, Linnell et al. (1995) found that, at least for ungulates, predators accounted for up to 67% of neonate mortality-surpassing deaths due to accidents, hypothermia, starvation, and disease. It would make sense then, for anti-predation tactics to be ingrained in every aspect of a fawn's life, and we would expect to see this played out in different ways throughout the study.

Even from before birth, anti-predatory strategies are in play. Does about to give birth often choose those areas with greater cover over richer, more optimal spaces in order to provide their young with a safer environment (Cuiti et al. 2006). In their studies of fallow deer, Cuiti et al. (2006) discovered that calving deer would more likely choose marshes over meadows, in contrast to their non-calving counterparts who preferred the open habitats with greater food resources over the well-protected marshes (Cuit et al., 2006). This can be quite dangerous, however, as fawn mortality has been shown to increase when habitat quality (as determined by the presence of preferred plant species) is diminished (Pettorelli et al. 2005). After birth, fawns tend to stay with their mothers until at least seven months old, when they are completely weaned (Feldhamer et al., 1988). This means that the fawn should inhabit the same habitats chosen by the mother and her group for several weeks, even after the neonate stage. This presumption has unfortunately not been researched enough to support the theory of that particular relationship.

Like many other species of cervids, fallow deer fawns are left shortly after birth by their mothers in a safe and hidden place, where they remain until retrieved (Gilbert, 1968). The general area is chosen by the mother, but the fawns are responsible for deciding exactly where to hide (Lent, 1974). The fawns are visited for nursing and socializing, and they always return to the hiding

spot when any threat is perceived (Gilbert, 1968). It is due to this behavior that fallow deer are referred to as an ungulate hider species. When hiding, deer fawns lie down with their heads and ears lowered in a prone position (Lent, 1974). Fisher et al. (2002) argued that this behavior is not only beneficial in defense against predators, but also as a means to conserve energy, which results in a faster growth rate and an expedited weaning date. Hiding can continue for several weeks with weak stimuli, although when greater threats are present, the fawns will choose to flee instead of hide within the first few weeks after birth (Espmark & Langvatn, 1985). The exact time of this change is not known, but Espmark and Langvatn (1985) suggested that it may have more to do with physical development than age, as they found that fawns with lower birth weights tended to stay hiding longer. After 3-4 weeks, the fawns follow their mothers rather than staying hidden (Feldhamer et al., 1988).

Male deer tend to have higher pre- and postnatal growth rates, and their adult condition is often more strongly related to their state after weaning than their female counterparts (Birgersson & Ekvall, 1997). In general, growth rates for deer fawns vary, and tend to be correlated with their mothers' body mass, along with birth dates and birth weights (Birgersson & Ekvall, 1997). Since these patterns have been documented in many studies featuring large herbivores, it is highly unlikely that we should see anything different with regards to the present study.

Dispersal generally occurs within the first two years of life; though the exact date can vary (Nelson & Mech, 1984, Shaw et al., 2006). The ratio of male to female dispersers is usually quite high, with the males eventually joining with others to form bachelor groups (Nixon et al. 2007). Nelson and Mech (1984), in their study of white-tailed deer, found that young males start to dissociate from their mothers and explore new territory at around twelve months, and begin establishing new home ranges at around seventeen months. This would imply that males who migrate should be seen at greater distances from this point on. Nixon et al. (2007) found a higher tendency to disperse in those whose mothers had dispersed, and higher dispersal rates as population density increased within a group. Females are less likely to leave the home range, but when they go, they are usually in small groups, and though distances of dispersal may vary, they can end up being comparable to that of males (Feldhamer et al., 1988). In spite of the fact that there has been much research done on emigration in large herbivores, specific details about distances and differences between individuals still remain unknown.

To respond to some of the gaps in previous research, this project takes a deeper look at anti-predator behavior, dispersal, and habitat choice in fawns. It also attempts to better understand how behavior in deer fawns is correlated with age in order to be able to predict age solely on behavioral factors.

Materials & Methods

Study Area

The study was performed at the Koberg estate (Figure 1) in south western Sweden (58° N, 12° E) in Västra Götaland County. The study site is 81.5km² split in two by a fenced road, and consists of forest (79%), arable land and pastures (16%), mires and marshes (2%), and lakes, ponds properties and parks (3%). A more complete description of the habitat types can be seen in the Appendix (Table 9). In addition to fallow deer, a number of other species of ungulates are present within the estate, including moose (*Alces alces*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), and red deer (*Cervus elaphus*), all of which are managed intensively along with the red fox to desired population densities. The predation threat for deer is comprised of the red fox, and also the wolf (*Canis lupus*) and the lynx (*Lynx lynx*), which are occasionally present in the study area. The red fox is the primary threat for deer fawns within the Koberg estate.

Data Collection

Over the span of three summers, a team of researchers went to Koberg to gather information about the deer fawns in the surrounding area. The data they collected was the basis for my research. Teams of biologists went and sought out fawns, either searching areas near solitary females in the proximity of groups, or following the females to where they hid their offspring (Kjellander et al., 2012). They compiled data for 82 fawns (38 males and 44 females) caught within the first few days of life (Table 1), which included both behavioral and physiological aspects of each capture, as well as detailed notes (See Appendix, Figures 12 and 13.) The deer caught were fitted with VHF or VHF/GPS collars, and were weighed, measured, and checked over. Specific observations about reactions during, before, and after capture, as well as body positioning and vocalizations made by the fawns were recorded as well.

The fawns in 2008 and 2010 were fitted with VHF transmitters (Televilt, Lindesberg, Sweden), and those caught in 2009 received either a VHF (N¼ 21) or a VHF/GPS (N¼ 3; Telemetry solutions, Concord, California, USA) transmitter. Coordinates were recorded every hour.

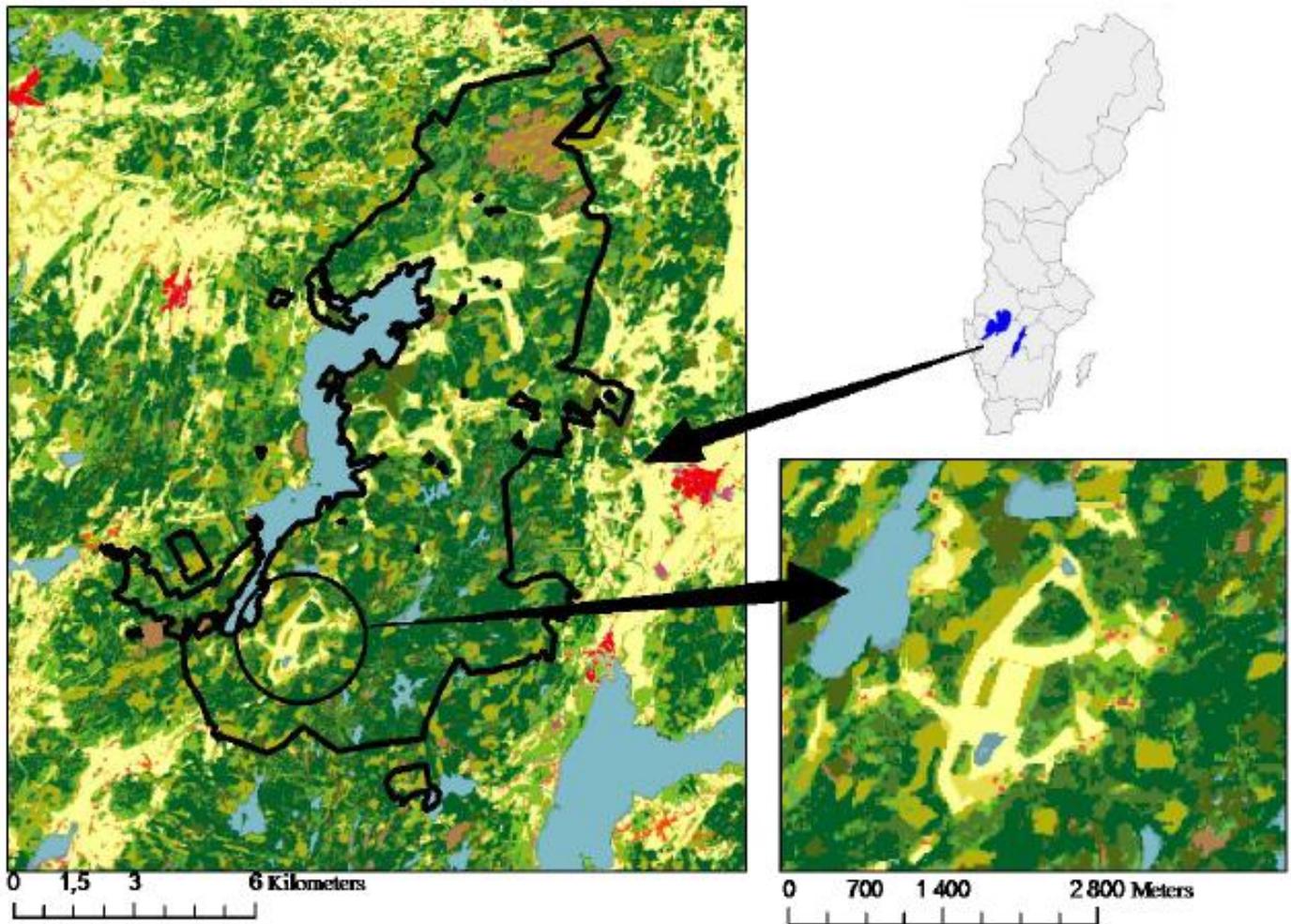


Figure 1. Map of the Koberg estate in south western Sweden as taken from Christensson 2010. Magnification increased from the whole of Sweden (upper right), to the area of the Koberg estate (left), to Lived (bottom right), an area with a high population density of fallow deer. Maps reproduced with permission: ©Lantmäteriet 2010. Permission 2010/0055

Table 1. Numbers, sex, and mortality of neonate fallow deer fawns marked at Koberg in south-western Sweden in 2008, 2009, 2010.

	2008	2009	2010	All years
Number Marked	15*	24	31	70
Males	6	12	13	31
Females	9	12	18	39
Number Dead	3	5	4	12
Males	1	4	2	7
Females	2	1	2	5

*) 3 fawns in 2008 only ear-tagged; 1 male and 2 females.

The habitats of the fawns were compared with those of 14 unrelated fawning female deer in the area, who were also fitted with GPS collars. With these females, coordinates were taken every fourth hour, and data was divided into two periods to signify the times before and after fawning. Coordinates taken from April 14th until two weeks before fawning were considered *before*, and the coordinates recorded at the date of fawning until two weeks after fawning were considered *after*. Individual fawning dates ranged from June 24th to July 2nd.

The areas were monitored for the years during the study, as well as two additional years, to follow the continued growth of the study fawns. Locations where adult deer were seen were noted during distance sampling, behavioral monitoring, or by chance sightings.

Mortality

Data from all three years was compiled, and fawn mortality was estimated for the first 20 days of life. Since the estimated birth date for each fawn is set to 1, the Kaplan-Meier method (Kaplan & Meier, 1958) was chosen in order to allow for animals to enter the study at different times. The log-rank (Mantel-Cox) test was employed to find differences in survival rates between males (N=30) and females (N=40). The weights at catching were also compared with their fate: survival or death, to seek out a correlation between the two.

Growth

In the three years of the study, 32 deer were caught twice or more. The data from these deer was used to generate an average daily weight gain for the first 15 days of life. Graphs were made to compare differences between the sexes and between ages. A general linear mixed model was then used to analyze the interaction between sex and age for weight gain per day. Age was entered as a continuous factor, and sex as a categorical predictor. An additional linear mixed model was also done to compare weight with age and sex, in order to include those fawns that had not been caught multiple times. Age was entered as a continuous factor, and sex as a categorical predictor. Fawns that did not survive were not included in either analysis.

Physical and Behavioral Comparisons

The behavioral traits at catching for all three years were taken for a total of 103 catches and catch attempts. Ages were estimated from several physical measurements, including the state of the umbilical cord, whether or not birth fluids remained on the fur, and the presence of polythene-textured covering on the hooves. For reaction, the range was from 1-4, where the numbers signify that the fawn: 1- doesn't move; 2- attempts to flee; 3- runs into the net; and 4- escapes. For head position, the range was from 1-2, with 1 representing a lowered head and 2 representing a raised head. For ear position, the range was from 1-3, signifying: 1-relaxed ears, 2-active ears, and 3-tense ears. Descriptions of other behavioral reactions can be seen in the appendix, Table 10.

Galli et al. (2008) found that a reliable way to age neonates in the first week of life was to observe the state of the umbilical cord; a wet, bloody cord signified a newborn, and it deteriorated daily until it became dried and brown around day 4, and fell off within the next few days. Therefore, behavioral measures were compared with the physical measure of the umbilical cord appearance, which was presented as bloody, some blood, dry, or none. Relationships between umbilical cord appearance and head position, ear position, and reaction at catch were investigated using a multiple regression analysis. Spearman rank correlations were then used to compare behavioral descriptions (reaction, head position, ear position, flight distance upon approach, screaming during handling, reaction after handling) with age. As fawns seldom fled, male and female flight distances were combined in this category.

Habitat and dispersal

A map with a resolution of 25 m² was made, which consisted of eighteen different habitat types and was based on a satellite generated digitalized map "Swedish Land Survey of Sweden" (SMD, National Land Survey of Sweden.) For the comparison purposes of this study, some of the habitat types were combined and the water habitats were deemed uninhabitable and left out. The remaining habitats consisted of Arable land, Pastures, Broad-leaved forests, Coniferous forests, Coniferous forests >15m, Mixed forests, Clear-felled areas, Younger forest, and Mires.

To estimate the type of habitats each deer occupied as a fawn, GPS positions from the fawns' collars were analyzed using ArcGIS version 10.0 (ESRI, Redlands, California). The Minimum bounding geometry (HULL) function was used to create polygons for every individual which had ten or more data points, N=21. Those with less than ten data points were not considered in this portion of the study.

Data regarding the home ranges of fourteen females who were non-related, but also living within the Koberg estate, was compared with the fawns' home range data. A Mann-Whitney U test was used to compare home ranges of the deer fawns with those of the adult does after fawning.

Center points of the fawns' polygons were determined using the Feature to Point function in ArcGIS Toolbox. For fawns with less than ten data points, the last coordinates taken as fawns were used as reference points instead. Including fawns with fewer data points, the sample size was a bit larger (44 fawns), and included more sightings (N=90). The Point Distance function was then used to measure distances between either center points or reference points and current sightings of the deer to estimate dispersal distance. A General Linear mixed model (two-tailed) ANOVA was used to seek correlations between age and sex, and dispersal. The distances to birth sites were entered as dependent variables, sex (categorical factor) and age (continuous factor) were explanatory factors, and animal ID was a random factor.

This project is managed by Professor Petter Kjellander and Dr. Ulrika Alm Bergvall, from the Grimsö Research station, for the Swedish University of Agricultural Sciences, Department of Ecology. All statistics were done using STATISTICA 7 (Statsoft inc. 2007).

Ethical approval for this study was granted by the Gothenburg Board for Laboratory Animals (Dnr: 187-08 & 405-08).

Results

Of the 82 deer caught over the three years, 18 (9 females, 6 males) were caught in 2008, 29 (12 females, 12 males) in 2009, and 35 (18 females, 13 males) in 2010 (Table 1). Of these, a total of 12 deer did not survive the first few weeks.

Mortality

Mortality was quite low with 12 in total: 3 in 2008, 5 in 2009, and 4 in 2010. The weight at marking appeared to have no effect on fawn mortality (Figure 2) ($p=0.095$). However, variance was high for those who died ($F=3.94$, $p=0.02$).

The Kaplan-Meier test (Figure 3) gave a cumulative mortality rate of 18.9 % (± 0.05 SE) for all deer fawns in all three years. Fawn deaths were highest immediately after birth, after which they decreased and stabilized around day 6. The rates for the sexes divided were 15.2 % (± 0.06 SE) in females and 27.3 % (± 0.8 SE) in males, showing a trend towards male-dominated mortality ($df=1$, $P=.20$).

Growth

Of the fawns which were caught twice or more, twenty were males and twelve were females. The males of the group showed a trend towards higher growth rates (slope=0.84) than females (slope=0.67) (Figure 4). Weights ranged from 4,300 to 11,040 in males and 3,880 to 8,090 in females.



Figure 2. Weight at marking versus Destiny in fallow deer from 2008, 2009, 2010. Data is presented as mean and standard error.

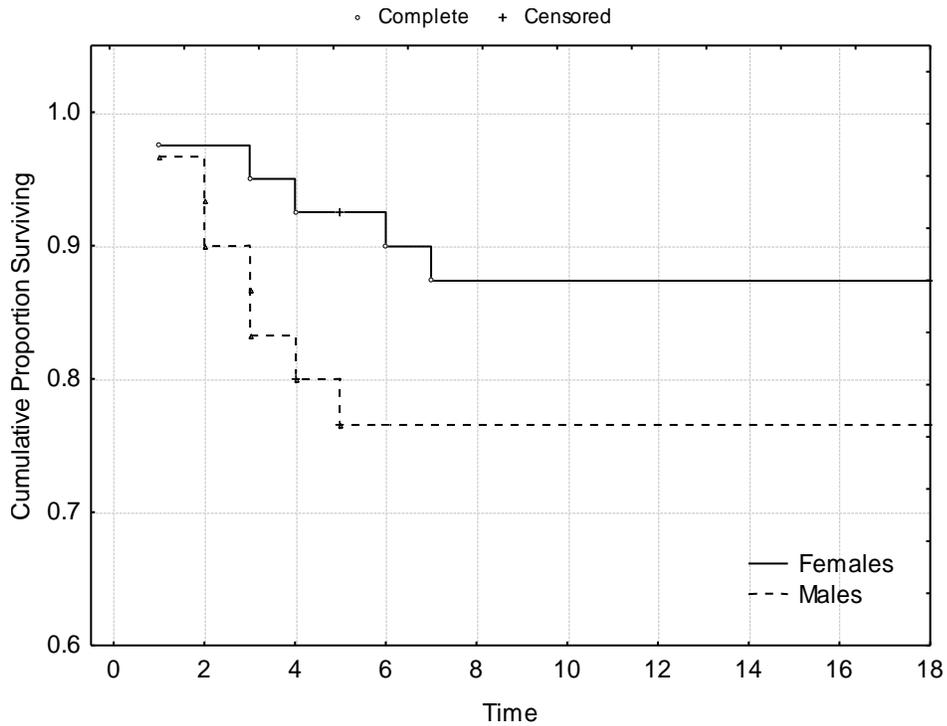


Figure 3. Cumulative survival rates for Koberg estate deer fawns in 2008, 2009, 2010 in first 20 days of life. Males (solid black line, N=30) females (dotted black line, N=40). Censored (+) signifies an unknown destiny due to collar loss.

Weight gain per day for fawns varied between 43 grams/day to 660 grams/day (Figure 5), and increased linearly with age. The general linear model for growth rate (Table 2) as related to age and sex supports this connection between growth rate and age; as fawns grew older, they developed faster ($p < 0.0001$). Sex however, did not appear to have an effect on growth rate ($p = 0.42$). This increase in growth rates with age did not differ between the sexes, as the interaction between sex and growth rate was non-significant (Table 2) ($p = 0.30$). At this stage in life, there is no obvious difference between male and female growth rates. However, the second linear mixed model (Table 3) comparing weight with age and sex ($N = 97$) found both correlations with the two variables; sex ($p = 0.044$), and age ($p < 0.0001$). The growth rates were comparable between the sexes, whereas the weights of the males were consistently greater.

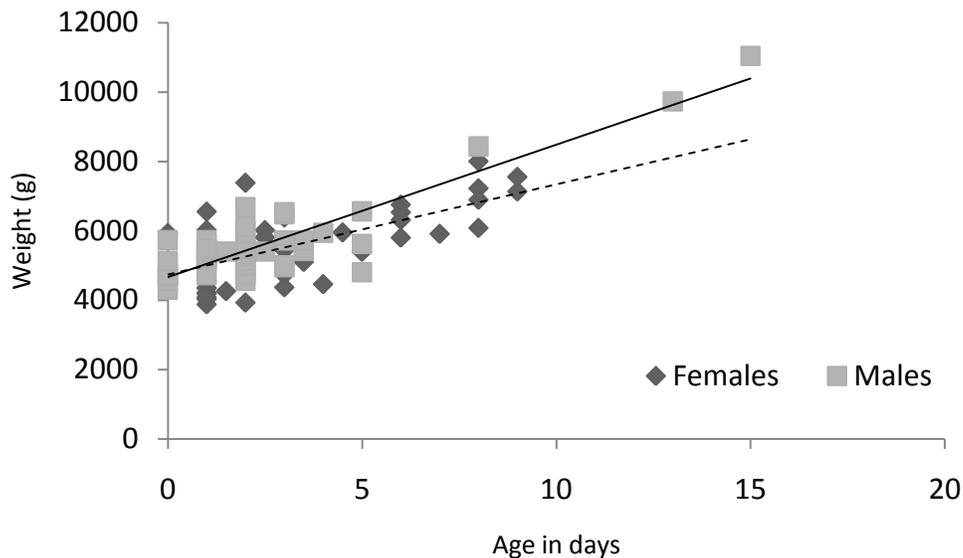


Figure 4. Age versus weight in 97 deer fawns from 2008-2010 during the first 15 days of life.

Table 2. General linear model for the effects of sex (categorical predictor) and age (continuous factor) and the interaction between sex and age for weight gain per day in fallow deer fawns. Data is for the first fifteen days of life from 2008, 2009, 2010.

	SS	df	MS	F	p
Sex	3957	1	3957	1	0.42
Age	765244	1	765244	128	<0.0001
Sex*Age	6623	1	6623	1	.30
Error	161209	27	5971		

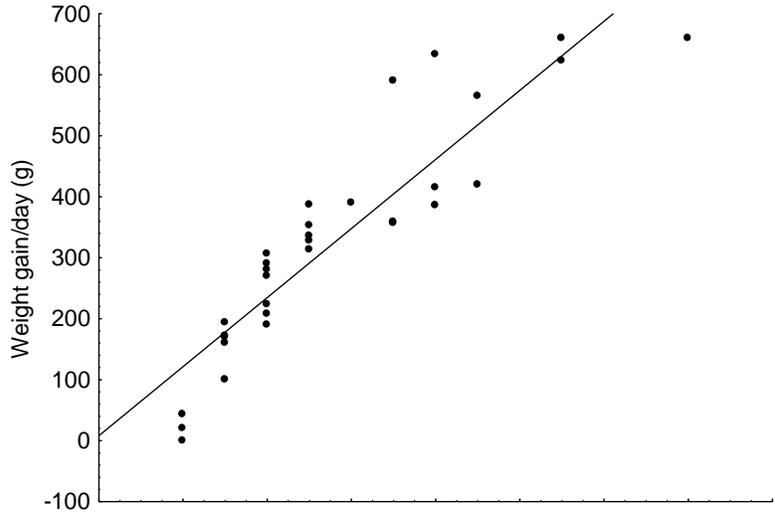


Figure 5. Weight gain per day in grams versus average estimated age between two weights in days. Data is from 32 deer fawns from 2008-2010 during the first 15 days of life.

Table 3. General linear mixed model for the effects of Age and Sex on weights in fallow deer fawns. Data is for the first fifteen days of life from 2008, 2009, 2010.

	N	F	p-level
Sex	97	4.2	0.044
Age	97	132.3	<0.0001

Physical and Behavioral Comparisons

The behaviors that were most strongly correlated with age (Table 4) were reaction ($r=0.54$, $p<0.0001$) and flight distance ($r=0.81$, $p<0.0001$). Head up was also correlated, especially in females ($r= 0.52$, $p<0.0001$). This implies a strong association between many behaviors and physical measurements of age. Fawns, as they got older, lifted their heads and ears more, and engaged in flight more readily. The weakest relationships were found between age and screaming ($r=-0.26$, $p=0.0055$) and behavior after handling ($r=-0.30$, $p=0.0020$). These factors do not change in a linear manner as the fawns grow.

Table 4. Behavior in relation to age for reaction, head position, ears and flight distance when approaching fawn, and for screaming during handling and the behavior after the handling. Spearman rank correlation.

		r	r ²	t	P	N
Reaction	All	0.54	0.29	6.49	<0.0001	103

	Males	0.37	0.14	2.34	0.025	37
	Females	0.66	0.44	7.1	<0.0001	66
Head up	All	0.44	0.20	4.93	<0.0001	102
	Males	0.35	0.12	2.34	0.025	41
	Females	0.52	0.27	4.62	<0.0001	61
Ears	All	0.35	0.12	3.75	0.0003	101
	Males	0.37	0.14	2.49	0.017	40
	Females	0.34	0.12	2.79	0.007	61
Screaming	All	-0.26	0.07	-2.83	0.0055	109
	Males	-0.39	0.15	-2.78	0.0079	46
	Females	-0.16	0.02	-1.23	0.22	63
Behavior after handling when put back.	All	-0.30	0.09	-3.17	0.0020	106
	Males	-0.13	0.02	-0.82	0.42	41
	Females	-0.41	0.17	-3.57	0.00069	65
Flight distance	All	0.81	0.66	8.29	<0.0001	38

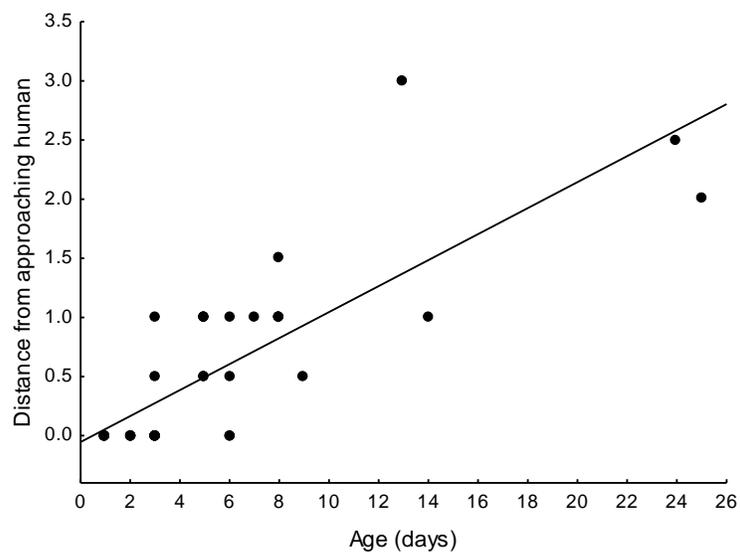


Figure 6. Distance in meters from approaching humans versus age in days during 38 catches and catch attempts from 2008-2010. Age is estimated from physical measurements.

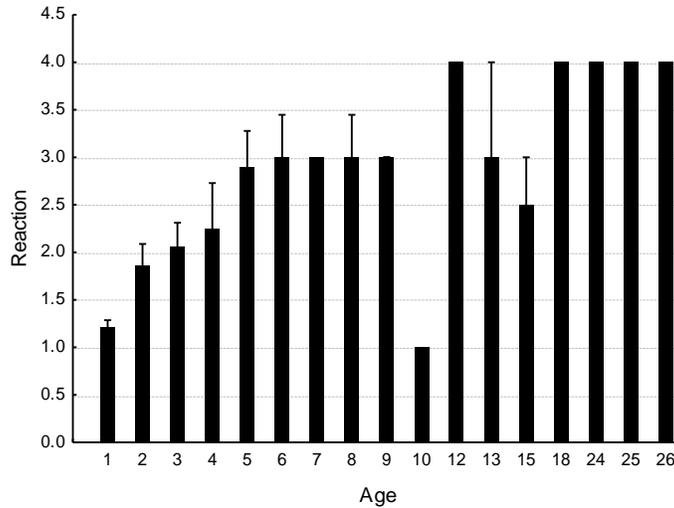


Figure 7. Fawn reaction to being caught versus age during 103 catches and catch attempts from 2008-2010. Data is presented as mean and standard error. Reaction ranges from 1-4, where 1 signifies a calm, still fawn, and 4 signifies a fawn who flees. Age is in days, and all ages are estimated from physical measurements. The first day is labeled 1 and all ages are estimated from physical measurements. The age at the second catch is: age at first catch + days between catches.

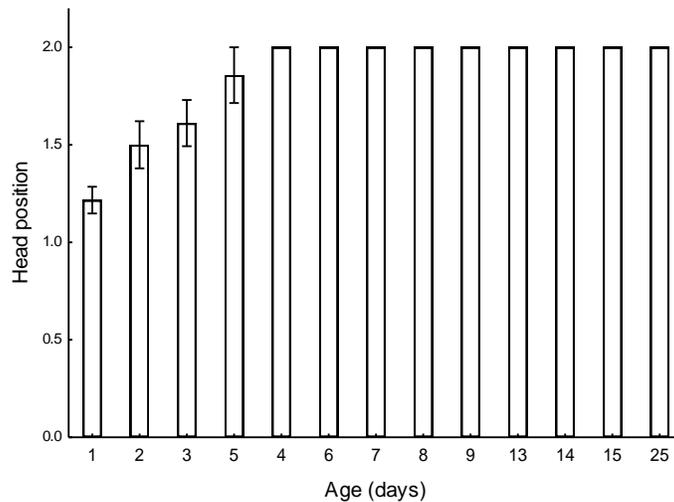


Figure 8. Head position at time of catch versus age during 103 catches and catch attempts from 2008-2010. Data is presented as mean and standard error. Reaction ranges from 1-2, where 1 signifies a lowered head, and 2 signifies a raised head. Age is in days, and all ages are estimated from physical measurements. The first day is labeled 1 and all ages are estimated from physical measurements. The age at the second catch is: age at first catch + days between catches.

Only some fawns successfully fled when approached by the capture team, which resulted in a smaller sample size for the comparison of Flight distance versus Age (N=38.) The relationship

between the two (Figure 6), however, was strongly related in a linear manner with few outliers ($r= 0.81$, $p<0.0001$.)

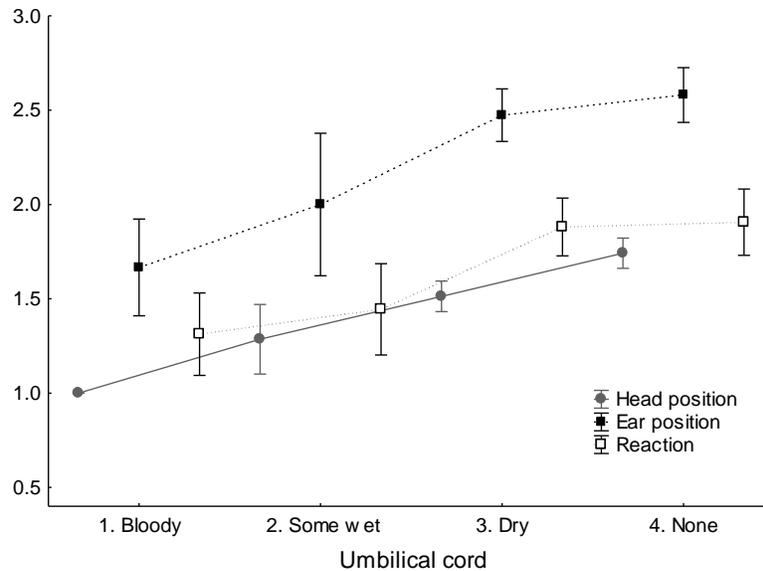


Figure 9. Comparison of physical versus behavioral measure of umbilical cord appearance for 103 catches and catch attempts between 2008-2010.

Head position and reaction both escalated with increases in age (Figure 7, Figure 8). The state of the umbilical cord (which signifies changes in age), was in line with the behavioral data (Figure 9); as the cord deteriorated and fell off, you can see corresponding changes in Head position, Ear position, and Reaction. This suggests that the four types of data can predict the same age in many cases. Of these three, the best predictor for age was head position ($\beta= 0.45$, $p=0.0009$) (Table 5).

Table 4. Multiple regression for Umbilical cord and Head position, Ears, and Reaction

	Beta	Std.Err. Of Beta	t(82)	p-level
Head position	0.45	0.13	3.45	0.0009
Ears	0.10	0.13	0.80	0.43
Reaction	-0.05	0.12	-0.40	0.69

Habitat and dispersal

Deer fawns had home ranges (Table 6) consisting mostly of Arable land (20.81%), Coniferous forests up to 15 meters (19.48%), and Coniferous forests greater than 15 meters (17.91%). The least visited habitats included Broad-leaved forest on mires (0.09%), Mixed forest on mires or

open bedrock (0.13%), Coniferous forest on open bedrock (0.23%), and Solitary houses with property (0.48%).

Table 5. Total habitat composition of 21 deer fawns' home ranges in Koberg, Sweden.

Habitat #	Habitat Type	Frequency	Habitat composition of home ranges (%)
5	Solitary houses with property	196	0.48
30	Arable land	8509	20.81
32	Pastures	2403	5.88
40	Broad-leaved forest not on mires or open bedrock	2179	5.33
41	Broad-leaved forest on mires	37	0.09
43	Coniferous forest on lichen-dominated areas	313	0.77
44	Coniferous forest 5-15m	7963	19.48
45	Coniferous forest >15m	7321	17.91
46	Coniferous forest on mires	1425	3.49
47	Coniferous forest on open bedrock	93	0.23
48	Mixed forest not on open bedrock or mires	1894	4.63
49	Mixed forest on mires	51	0.12
50	Mixed forest on open bedrock	3	0.01
54	Clear-felled areas	4078	9.98
55	Younger forest	2414	5.90
72	Other mires	846	2.07
81	Lakes and ponds open surface	644	1.58
82	Lakes and ponds with surface grown over	513	1.25

In comparison with the calving females, the chosen habitat appeared very similar (Figure 10), with both fawns and does preferring Coniferous forest (both greater and less than 15 meters) and Arable land more than any other habitat type. Our p-values for this relationship (Table 7) showed general trends supporting this relationship, with the only significant difference being in mixed forests ($p=0.02$).

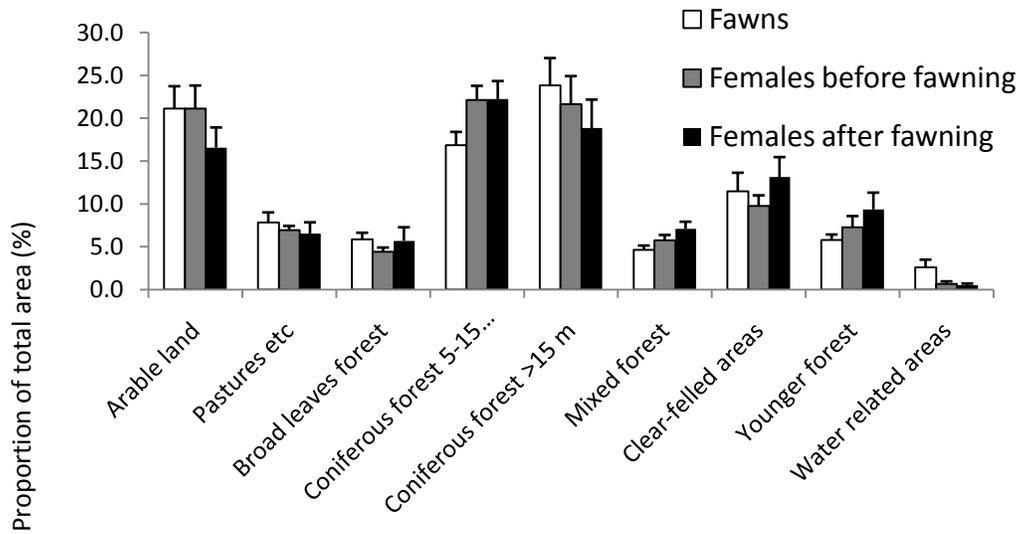


Figure 10. Proportion (in percentage) of total area of each habitat type for fallow deer fawns (white boxes), females before fawning (grey boxes), and females after fawning (black boxes).

Table 7. Comparison of habitat composition between fawns (N=21) and females after fawning (N=14). Mann-Whitney U Test.

	U	Z	P
Arable land	113	1.14	0.25
Pastures	127	0.67	0.50
Broad-leaved forest	110	1.25	0.21
Coniferous forest	95	-1.75	0.08
Coniferous forest >15m	122	0.84	0.40
Mixed forest	78	-2.32	0.02
Clear-felled areas	131	-0.54	0.59
Younger forest	106	-1.38	0.17
Mire	124	0.79	0.43

The graph for dispersal (Figure 11) show clear peaks for distance in both males and females around the 12 and 24 year marks. For females, the highest distances shown were at the 1 year mark and the 2 year mark at around 7500 and 8300 meters from the home range. Following the same time periods, the maximum distances for males were 6500 meters and 7100 meters, respectively.

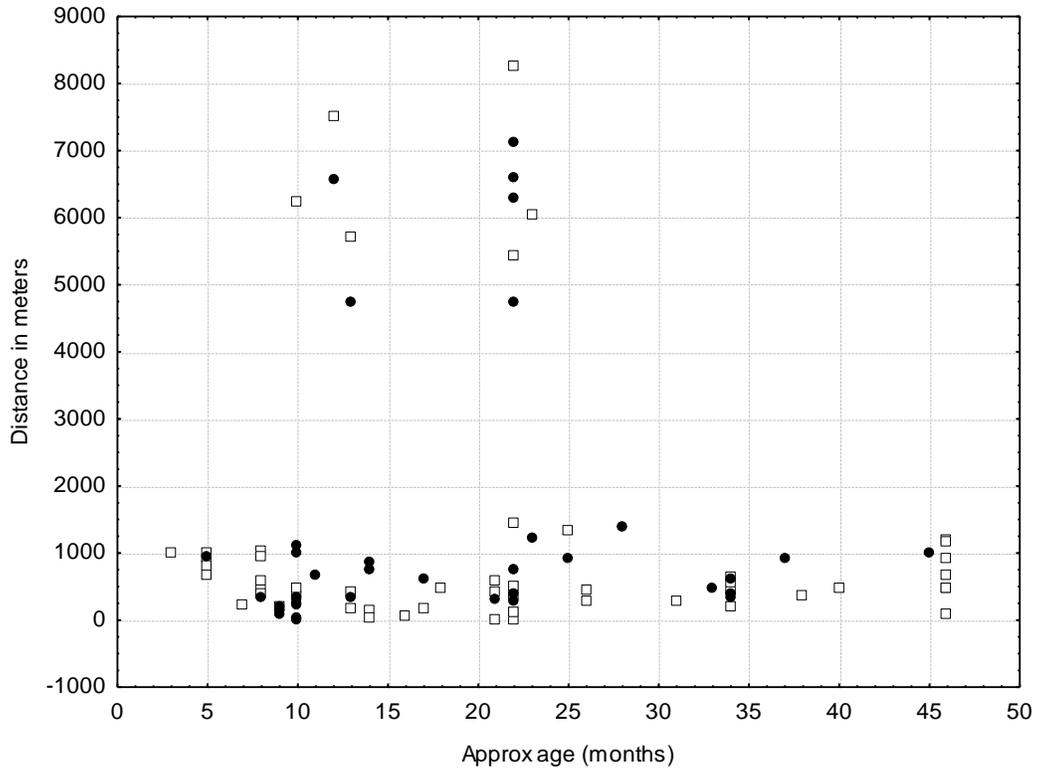


Figure 11. Dispersal distance in meters versus age in fallow deer fawns in Koberg, Sweden. Males are indicated by black circles (●) and females by white squares (□)

The deer in our study didn't disperse more as they aged or in reference to sex. The ANOVA test (Table 8) gave no indication of significant linear correlations between dispersal of fawns and their approximate age ($p=0.96$), sex ($p=0.70$), or the two factors combined ($p=0.44$).

Table 8. Two-tailed, general linear mixed model ANOVA for Dispersal and Sex, Approximate age, and Sex*Approximate age.

	Effect (F/R)	SS	Degrees of freedom	MS	F	p
Sex*Approx age (months)	Fixed	2509400	1	2509400	0.60	0.44
Sex	Fixed	610075	1	610075	0.15	0.70
Approx age (months)	Fixed	12820	1	12820	0.0031	0.96

Discussion

The mortality rates in this study were quite low ($\approx 19\%$), likely due to the paucity of predators. However, red fox in the area still present a threat to fawns, so we were curious as to why the rates are still so low. Some research has shown that in addition to providing their offspring with safer habitats, does also provide protection from predators, whether in the form of distraction to lead the predator away (Severinghaus & Cheatum, 1956), or by actually attacking the predator and causing it to retreat (Garner & Morrison, 1980). In their studies of white-tailed deer, Ozoga and Verme (1986) found that as does grew older and more experienced (≥ 3), they had disproportionately fewer losses of fawns to predators. This leads us to believe that females learn to protect their young, and with each fawning, they improve their skills. It may have provided us with more insight to know the details for the mothers of our fawns, but perhaps that is out of the scope of this particular study.

The lack of statistical support in the comparison of weight at capture versus mortality rate goes against the majority of work done on the subject. Fairbanks (1993) found that low birth weight was directly correlated with increased mortality in pronghorn fawns, and Vreeland et al. (2004) acquired similar findings in their work regarding white-tailed deer. We can only assume then, that our small sample size ($N=12$) led to a biased result. The high variance in the deceased deer further augments our assumptions, as this can be a sign that the findings are skewed. Given a larger sample size, it is likely that results would be more in line with those of other researchers.

Our growth rates radically differ from most studies regarding differences between the sexes, but the fawns in this study were very young. Our results could be due to a random error, or it could have been affected by the varied times at which the fawns were measured. An alternate hypothesis could be that male deer increase their growth rate after the first few weeks of life, which is possible, although Birgersson and Ekvall (1997) argue that selection has acted directly on males to grow more rapidly than females, both before they are born and in the weeks after. If this is true, the specific variables that play a part in the differences seen here could be a mixture of several different factors. Case (1978) argues that infant mortality is a plausible variable in the growth rate equation for interspecific and perhaps even intraspecific variation, along with other features of the environment. In his research, he found that in species where males grew faster than females, they also had significantly higher neonatal mortality rates; whereas in species where females grew faster, the mortality rates were almost equal (Case, 1978). Depending on the reasons behind these patterns, the low death rates in both males and females in Koberg could produce the similarities in growth rates seen here. Conversely, the fact that only some of the deer were caught twice or more could have an effect on this anomaly. The inclusion of deer only caught once, and the subsequent slope analysis and additional mixed model show a somewhat different result, where the males had larger slopes, and the weights were strongly correlated with sex and age. This leads us to believe that our growth rates may be slightly skewed due to a small sample size.

The tendency for deer fawns to choose coniferous forests and arable lands over most other habitats reflects an innate desire to remain hidden from predators. Grovenberg et al. (2010) found, that for every 1 cm of understory growth, bed-site selection of white-tailed deer increased by 3.5%. Despite the paucity of predators within the Koberg estate, the anti-predation instincts in this population remain. While studying other fawns in this area, Kjellander et al. (2012), found similar anti-predation behaviors where no predators could be found; their suggestion was that of „pleitropy,“ from Byers (1997), wherein a trait that served some initial purpose remained, even after that purpose was deemed unnecessary, because it served an alternate purpose. This could be the case in our findings, as hiding in forests or tall grass may have alternate benefits, such as protection from the elements or thermoregulation properties.

The similarity in habitats seen here between fawns and does after fawning is a good indication of the validity of our results, despite the scarcity of the data points compared with GPS marked animals. There have not been many studies relating these two variables, so there is not much room for comparison. However, given the close relationship of doe and fawn, as well as the desire for the doe to protect her fawn from predators, it is reasonable to say that the two should inhabit similar habitats for as long as possible. Panzacci et al. (2010) found that mortality by predation increased with distance between mother and fawn in roe deer. However, they also noticed that the does varied the distance between themselves and their fawns depending on habitat type; distances increased when fawns were hidden in well-covered areas so as not to draw attention to them, and decreased in more open, highly visible areas so that mothers would be able to quickly defend their young in case of emergency (Panzacci et al., 2010). This could be part of the reason why there was a significant difference when it came to mixed forests; the females may stay further away since there is likely a high amount of coverage in these areas. A closer examination of these types of areas within Koberg might show more clearly why there are some variations in habitat type here. Either way, the other habitats were quite similar, which would render the results compatible with the study of Panzacci et al. (2010), which found that the does were never more than 200 meters away from their young at any given time. Similar distances have been recorded in other studies (Hawkins & Klimstra, 1970 and Pettorelli et al., 2005).

The dispersal graph (Figure 11) shows very definite distance peaks for both sexes around the 12 and 24 month marks. While this could be due to inconsistent observation methods, it could also point toward a specific trend. It is entirely possible that either the deer disperse and then re-join the group at some point, or it may be that only those who have not emigrated have been seen after the peaks. In this study, only one male was seen in the close vicinity of the birth range, and that occurred within a month of being captured, which is well before dispersal has been completed. In white-tailed deer populations, young males have been seen periodically in the same area as that of the females including their mothers (Nelson & Mech, 1984). This can occur for up to three years, sometimes even after the bucks have established their own home ranges (Nelson & Mech, 1984). A male in our research with one of the highest distance peaks at one year was seen closer to his home range months after that event. This pattern supports the theory

that males can migrate back and forth to their home range before finally emigrating to a more permanent bachelor group. Data for female fawns is not as widespread because females generally do not disperse as often. In white-tailed deer, Hawkins and Klimstra (1970) found that although most doe yearlings remained in the same area as their mothers, it became more common after the second year to break away from the maternal group and move to a new territory. They also found that, not unlike the males, prior to finally dispersing, females would venture out and then rejoin the group periodically (Hawkins & Klimstra, 1970). The separation of families involving either sex seems to be a gradual one, with re-associations occurring less and less frequently over a period of two to three years. Although more research should be done to improve and build upon this idea, our results suggest that even if the relationship between age and dispersal distance is not a linear one, it does exist. The methods in estimating dispersal could be improved upon by implementing a method which can track all individuals in a similar manner. This is quite difficult in growing animals, but with some effort it could be possible. Despite not entirely flawless data, the graph shows an interesting result that should provide researchers with plenty of inspiration for new studies.

As predicted by many researchers (Galli et al., 2008, Haskell et al., 2007, and others), we saw results indicating that age can indeed be estimated, at least in some cases, by behavioral responses in deer fawns. In their works regarding hiding behaviors in captive red deer, Espmark and Langvatn (1985) argue that even if using some behaviors might help with estimating age in certain cases, the results may vary depending on species, location, population, or relative captivity. They also found that birth weight played a large role in how long a fawn hid; a 250 g decrease in birth weight added an extra full day of hiding (Espmark & Langvatn, 1985). This, combined with the difference in hiding time between species, from a few days in cattle and goats (Lent, 1974, O'Brien, 1984), to about a month in giraffes (Langman 1977), to up to 2 months as in reedbucks (Jungius 1970), could create a problem in making generalizations regarding age estimates and behaviors. However, for field observations of fallow deer fawns, we would argue that our results could be used to obtain general estimates of ages. Galli et al. (2008) had comparable findings, and suggested that with the use of both physical and behavioral traits, age can be reliably estimated, regardless of sex, so long as the people collecting data all quantified it in the same manner. This is true in our study as well; many of the characteristics were subjective, and thus universal definitions had to be agreed upon.

This study has provided results which gives rise to a better understanding of some of the more vital aspects of the neonatal stage in fallow deer fawns (*Dama dama*), including growth rate, habitat use, dispersal, and anti-predatory behaviors.

Information regarding deer fawns during the first weeks and months of life, as has been explored in detail throughout this study, contributes in the exploration of the blueprint that holds the future of the individual deer, the herd, and indeed its population dynamics.

The strong relationship between early growth conditions and individual quality, as observed by Hamel et al. (2009), in combination with the findings that individual quality corresponds with fitness (Hamel et al., 2009), and that life-history traits affect population demographics (Gaillard et al., 1998), suggest an interconnectedness within all life stages. More work engaged in following fawns throughout the entirety of their lives needs to be carried out in order to provide enough knowledge to grasp the complete picture of *Dama dama*.

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Appendix

Table 9. Habitat composition in the major study area at Koberg in south western Sweden (Winsa, 2008).

Habitat #	Habitat Type	Habitat composition in study area (%)
5	Solitary houses with property	.33
19	Non-urban parks	.36
30	Arable land	12.46
32	Pastures	3.97
40	Broad-leaved forest not on mires or open bedrock	3.37
41	Broad-leaved forest on mires	.10
43	Coniferous forest on lichen-dominated areas	2.51
44	Coniferous forest 5-15m	15.24
45	Coniferous forest >15m	28.79
46	Coniferous forest on mires	5.86
47	Coniferous forest on open bedrock	.48
48	Mixed forest not on open bedrock or mires	5.69
49	Mixed forest on mires	.28
50	Mixed forest on open bedrock	.02
54	Clear-felled areas	9.97
55	Younger forest	6.87
70	Water-dominate areas	1.72
71	Wet mires	-
72	Other mires	-
81	Lakes and ponds open surface	1.15
82	Lakes and ponds with surface grown over	.85

Table 10. Total habitat composition of all eleven female fallow deer home ranges in Christensson 2010.

Habitat #	Habitat Type	Area (km ²)	% of all home range areas
5	Solitary houses with property	0.10	0.32
30	Arable land	4.70	14.61
32	Pastures	1.63	5.05
40	Broad-leaved forest not on mires or open bedrock	1.29	4.03
43	Coniferous forest on lichen-dominated areas	0.33	1.02
44	Coniferous forest 5-15 m	5.10	15.85

45	Coniferous forest >15 m	8.44	26.26
46	Coniferous forest on mires	2.93	9.10
48	Mixed forest not on mires or open bedrock	1.51	4.71
54	Clear-felled areas	2.70	8.41
55	Younger forest	1.72	5.34
-	Water related areas	1.62	5.03
-	Mountain related areas	0.09	0.27

Table 11. Corresponding descriptions of ordinal scales given to behaviors of fallow deer in Koberg, Sweden.

Behavior	Description	1	2	3	4
Reaction	Reaction at capture, when the landing net was thrown over them	Remained in the freezing/hiding position	Attempt to escape, but caught in landing net	Attempt to escape, but caught in large net with poles	Escape!
Head up	Head position at time of capture	Low	High	-	-
Ear position	Ear position at time of capture	Relaxed flat against the neck	A little active but not raised	Tense and directed at captors	-
Screaming	Presence of screaming during handling	No screaming	Screaming		
Behavior when put back	Behavior after handling, when returned to original location	Remains standing in position	Moves towards captors	Walks away	Runs away
Flight distance	Distance from the closest captor when attempting to flee (ratio scale)	-	-	-	-

Figure 12. Field data sheet for behavior of fallow deer fawns in Koberg, Sweden.

FAWN BEHAVIOUR 2010

FAWNID nr: _____ DATE: _____
 NAME on Fawn: _____ TIME: _____
 Ear tags L: R: _____ Names on participants: | _____

Capture / Recapture / Survival check

Method: Landing net or Big net?

Below, choose the most appropriate choice with a circle

1. Prone position	Yes	In the beginning	No	N/A
2. Head position, when approaching the fawn	Low	High		
3. Ear activity, when approaching the fawn	None	Tense		
4. Reaction	Hiding	Try to run	Run in net	Runs away
5. Screaming	No	Somewhat	Yes	
6. Scream during ear tagging	No		Yes	N/A
7. Behaviour when put back	Still in position	Walk to people	Walk away	Run away
8. Hoofs	All white left	Some white left	Used	N/A
9. Fur	Wet	Little wet	Dry	N/A
10. Umbilical cord	Blood/wet	Little wet	Dry left	Gone
11. Females: Nr of:	Chased away	Comes	None	
12. Nr of persons				
13. Time for disturbance	Marking and searching		Only marking	
14. Run distance if the fawn runs away. (Distance from nearest person)				

Write a description about what happened:

Figure 13. Field data sheet for physical characteristics of fallow deer fawns in Koborg, Sweden.

MARKINGS OF FAWNS 2010

Date: 2010 - - - - - Marked by:

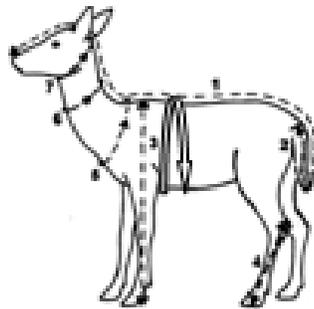
Time:
Start search in area: Start marking fawn: stop:

Time for disturbance incl search:

Time for disturbance only marking procedure:

ID Number		COLLAR MARKING	
Sex		Frequency	
Body temperature		Colour	
Fur colour		EAR TAGS	
Weight with collar and bag		Left colour	Right colour
Bag weight		umbilical cord	
Weight (excl. collar and bag)		Neurotoxic	
Meta tarsus (4)		Faeces (Y/N) colour	
Chest (white arrow)		Fur (dry/mostly dry/wet)	
DNA	YES/NO	Hoofs (white/some white left/used)	

Notes:



Location:		Habitat:		Time:
Mother GPS	X:	Y:		
Fawn GPS	X:	Y:		At marking

