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Department of Ecology
Grimsö Wildlife Research Station

Female Behavior Affects Offspring Survival in Roe Deer (*Capreolus capreolus*)

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Female Personality and Behavior Affect Offspring Survival in Roe Deer *(Capreolus capreolus)*

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Abstract

The concept of individual behavior and personality is a convoluted concept within ecology. In essence, how individual variations in behavior may affect an individual's success in survival and reproduction as compared to other individuals who behave differently. This study aimed to investigate how individual variation in primarily behavior, but also physiological differences, of roe deer (*Capreolus capreolus*) does affected fawn survival during the first two months of life. The study was based upon individuals captured in two areas of central Sweden. A number of variables attributed to behavior and physiology were gathered through trapping of roe deer, using baited box traps. Uncorrelated variables were progressively analyzed through a series of logistic regression models. Three variables were related to fawn survival based upon these models; the average spatial distance between mother and fawn, the mother's behavior during handling, and, to a lesser degree, release. The negative relationship between fawn survival and distance between mother and fawn is mainly tied to the success rate of protecting her fawn from predators with the doe's presence. Mother behavior during capture and release was concluded to be tied to levels of vigilance and boldness in the mother; individual behavior which seems to affect fawn survival.

Keywords: *Capreolus capreolus*, Mother Behaviour, Fawn Survival, Mother Personality.

Summary

Animal behavior is a difficult mechanism to scientifically evaluate, as it is subject to a myriad of different queues, circumstances and individual variations. Despite this, it is well established that behavior is an important part of animal ecology. The exact nature of how individual variations behavior effects different parts of animal ecology is however a work in progress. Reproduction, being a key biological process, is potentially very susceptible to these individual variations in behavior, especially in species where levels of parental care is high. Where the young is cared for by its parent or parents, the choices and behavioral quirks exhibited by those same parents could have a profound impact upon their offspring.

The Roe deer *(Capreolus Capreolus)* is a polygamous ungulate with a wide area of distribution in Europe and Asia. The species practices delayed implantation, which means that although the rut takes place late July and August, the fawns are not born until late May and early June. This enables the roe deer to perform two of the most energetically demanding activities in its life during summer, when food is abundant. During the first one or two months of its life, the fawn remains stationary, hidden in daybeds, until it starts to follow its mother around. During these early weeks of its life, the fawn is fully dependent upon its mother, who must return at regular intervals to feed it, but must also protect it from predators. This means that the mother must balance her own demands for food with that of her fawns.

Primarily, this study aimed to find if there were any links between variables tied to mother behavior and the survival rate of fawns. Among these variables were mother movement patterns, the average distance between mother and fawn, the cortisol levels of the mother, and how a mother behaved during capture and handling. Secondarily, this study also aimed to find if there were any links between variables tied to mother and fawn fitness and the survival of the fawn. These variables included mother age and weight, as well as fawn weight and body temperature. And lastly, the study also aimed to deduce if factors such as temperature and precipitation had any statistically significant impact on the survival rate of the fawns.

These goals were accomplished mainly by utilizing data from long time (1974-2016) monitoring of roe deer at Grimsö and Bogesund, two areas in south-central Sweden. This data included GPS-tracking through collared individuals, blood samples, measurements and behavioral evaluation from captured individuals, as well as measurements taken from local weather stations. Mortality data was also collected on all fawns, and since the time period of interest was the first two months of life, only fawns with recorded deaths occurring during the first 60 days of life were listed as deceased for the purpose of the study. The different variables and the mortality data were then used in different constellations to construct linear regression models to deduce which variables best explained the patterns of mortality.

The results indicated that there was a strong statistical relationship between the average distance between a mother and her fawn the survival rate of said fawn. The greater the average distances between the two, the greater the risk of the fawn dying during the allotted time period. In addition, the results also indicated that there existed a statistical link between how a mother behaved during capture, handling and release and the survival of her fawn. Lastly, there was inconclusive link between the cortisol levels of the mother and the survival rate of the fawn. The variables related to the physiological state of the mother and fawn, as well as weather conditions and temperature yielded no significant effect on fawn mortality.

A mother that stays further away from her fawn will decrease her ability to defend it against predator attack, and perhaps feed it less regularly, which explains the relationship obtained between average distance between mother and offspring and fawn mortality. However, she also increases her own food intake and foraging success by doing so. Likewise, a mother who exhibits higher levels of stress during capture may well exhibit an overall more vigilant personality with more protective tendencies than one who reacts to the trying conditions of capture in a more muted fashion. This in turn would explain the relationship between mother behavior during capture and fawn mortality. Regardless, these results indicate that there is indeed a link between individual behavior patterns in the mother and her reproductive success.

Keywords: *Capreolus capreolus*, Mother Behavior, Fawn Survival, Mother Personality.

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1.0 Introduction

The concept of animal behavior is a broad and general topic within ecology (Davies *et.al,* 2012). Although clearly of utmost importance for understanding mechanics of ecology, it does often exhibit a somewhat misleading flaw. Like so many other concepts within ecology, it is the flaw of generalization (Cain *et.al,* 2011). Ecology, at its fundamental level, is built around generalization, for without it, a coherent principle of ecology could not be formulated (Cain *et.al,* 2011). However, with this lack of a more nuanced and detailed approach, several key elements may well be lost (Townsend *et.al,* 2008). In speaking of behavioral ecology, one almost always speaks in terms of how an individual, group or population will act or behave based upon an average of the whole. Though sufficient at large scale predictions, one runs the risk of camouflaging how the unique individual behavior of a single entity may affect the whole.

Differences in behavior between individuals of the same species, and living under similar conditions may be attributed to what in a person would be labeled “personality” (Davies *et.al,* 2012) which is an important concept in the contemporary studies of wildlife behavioral ecology. Though these slight differences may be inadmissible when considering the whole population, it is often important to consider that the whole is a collection of parts (Davies *et.al,* 2012).

A crucial part of individual behavior is tied to reproduction, specifically in the context of parental care (Davies *et.al,* 2012). It is within animal groups that provide parental care, primarily mammals and birds, that individual behavior in regard to reproduction is easiest to detect. Although many animal groups may exhibit a certain degree of individual variability in the area of reproduction due to physiological differences between individuals, most animal groups do not exhibit any level of parental care. After the point of birth therefore, the parent’s individual behavior or characteristic will cease to act upon its offspring, barring purely inherited factors (Beebee & Rowe, 2008).

Because of this, mammals make the best targets for investigation on individual behavioral traits and their effect on the individual’s reproductive success, as they often exhibit a high amount of parental care (Hickman *et al.,* 2012). However, while studying this phenomenon, it should be taken into account that targeting social mammals present another layer of difficulty, as it may be difficult to discern which factors can be attributed directly to the offspring’s parents, and which should be attributed to the group in which the parents reside (Davies *et al.*, 2012). Because of this, largely solitary, non-cryptic mammals with a high level of maternal care make the obvious targets for this the kind of investigatory study conducted here. Because of this, this study chose roe deer (*Capreolus capreolus*) as its study species.

Roe deer is one of the relatively few modern success stories in a world where wildlife is under constant and ever increasing pressure caused by anthropogenic activities, being labelled as a very common species with few current threats by the International Union for Conservation of Nature (IUCN, 2017). Currently, roe deer are spread widely over most of Europe, barring some of the northernmost areas, and parts of Asia. The key to the roe deer’s success is partly due to the enormous level of adaptability it exhibits as a species (Andersen *et al.* 1998). Another major component is its compatibility with anthropogenic enterprises.

1.1 Sweden's Roe Deer Population

In Sweden, the roe deer population was almost hunted to extinction during the late 17th and early 18th century and by 1850 only a small population was left alive in the southern areas of the country. However, the population recovered and spread, reaching as far as Norway. The Swedish population stabilized at around 250.000 animals during the middle of the 1900-hundreds. Towards the late 1900-hundreds the population exploded in number, reaching as many as over one million individuals. This drastic increase in population size is mostly attributed to the outbreak of sarcoptic mange in the country, which drastically decreased the population of predating red fox (Aguirre et al., 1999).

Currently, roe deer remains a stable component of the Swedish ecosystem, even though the population size itself swells and dwindles sharply, depending mainly on winter severity (Cederlund and Lindström, 1983; Davies *et al.*, 2016), but also on predation from red fox and Eurasian Lynx (*Lynx lynx*) (Linnell *et al.*, 1995), and combine harvesters (Jarnemo, 2002). Due to widespread forest industry in Sweden, roe deer also come into conflict with humans, due to damages on commercial tree plantations from foraging and rubbing its antlers while engaging in either territory marking or cleaning the antlers after shedding the velvet (Andersen and Linnell, 1998). Sweden also harbors a powerful tradition of hunting, and roe deer is an important game animal, with roughly 100.000 individuals being shot each year (Swedish Hunting Association, 2014/2015).

1.2 Adaptations

Within the northern areas of its distribution, in particular Scandinavia, roe deer face the challenging prospect of harsh winter temperatures, deep snow and a much shorter growing season than in southern climes. A thick layer of snow is particularly problematic, increasing energy cost of locomotion and making access to food more difficult (Davies *et.al*, 2016). In these regions, the roe deer's adaptability presents itself in a variety of forms. Several are common among generalists, such as feeding upon a wide array of plant species. Physiological adaptation includes a thicker pelage and an increased ability to store fat, though the fact remains that the roe deer's ability to store fat is relatively constrained as opposed to other northern cervids. Because of this, roe deer must rely more readily upon foraging rather than accumulated fat reserves (Aanes *et.al* 1998). Thus, the majority of its energy economy must be based on foraging, even during winter. Due to this inability to store large reserves, the roe deer is forced to base its reproductive success upon resources gathered during the reproductive period, making it a so-called "income breeder" (Andersen *et al.*, 2000). This as opposed to a so called "capital breeder" that bases its reproduction upon stored reserves (Jonsson, 2017). Being an ungulate and an income breeder makes the roe deer something of a rarity, as most ungulates tend to be capital breeders (Andersen *et al.*, 2000).

1.3 Reproductive Strategy

Roe deer females make use of delayed implantation, meaning that the implantation of the embryo into the uterus wall is delayed some five months from the time of actual mating and fertilization. This enables both of the most energy demanding periods it's life cycle, the rut and the fawning season, to occur during the summer months, when resources are abundant. The rut takes place in late July to early August, and the rate of fertilization is high, with 98% of the females being fertilized within a short period of time. This short period of fertilization means that the fawns are all born within weeks of each other, in late May early June (Gaillard *et al.*, 2017). This synchronization of births is also maintained by individual mothers tending to give birth at similar times from one year to the next (Andersen and Linnell, 1998).

But unlike similar birth synchronization found in other organisms, that of roe deer does not seem to act as a defense mechanism against predation. Often, such tactics are used to provide potential predators with an overabundance of prey, or "target saturation", ensuring that the number outliving the dangerous prenatal stage is maximized. But in roe deer, this synchronization of births seems to be primarily a mechanism to mesh time of birth as effectively as possible with the time of spring flush and peak forage productivity (Plard *et al.*, 2013).

1.4 Challenges of Reproduction

Like most ungulates, the mortality rate of roe deer is bell-shaped, with the vast majority of deaths occurring during infancy and senescence (Andersen *et.al*, 1998). Following birth, fawns are subject to a wide variety of different threats. First, amongst these is the risk of predation (Linnell *et al.,* 1995), by red foxes (Jarnemo, 2004). The second largest threat is anthropogenic activity, in the shape of hay mowing of fields wherein the fawns make their daytime bed-sites (Jarnemo, 2002). Other important mortality causes include trauma, pneumonia and an assortment of infectious and bacterial diseases (Aguirreet al., 1999).

Since the prime mortality cause for roe deer fawn is predation; roe deer have developed a cryptic behavioral defense mechanism, and rely heavily on the cover provided by dense forest and scrublands to avoid detection. Unlike other cervids, the roe deer is not a cursorial ungulate, and is unable to run at high speeds for any length of time (Andersen *et.al*, 1998). Outpacing their attacker is therefore not a prime defense. This is particularly true of fawns, which are especially vulnerable, which, during the first 1-2 months remain hidden in day-beds rather than following their mother (Andersen *et al*., 1998). Due to the danger to their fawns during the first few weeks of life, the doe must balance their own need of foraging with that of protecting their young (Panzacchi *et al.*, 2009). The presence of the doe has been proven to offset predation of her fawn by red foxes, with the doe often deterring the fox (Jarnemo, 2004). Red Foxes also stand for a substantial part of neonatal fawn mortality, often more than 60% (Panzacchi *et.al*, 2009) and sometimes as high as 88% (Jarnemo and Liberg, 2005) depending upon fox density and habitat composition. As such, defending her fawn is a crucial part of maternal care. However, spending too much time guarding her fawn impedes her ability to forage, and thus impacts her physical state and the quality of the milk she provides.

This demand to balance the need of her offspring with her own needs increases the stress on the mother during the fawning period. Challenging circumstances give rise to an array of coping mechanisms that are unique between mothers, depending on how each given doe experiences and copes with these stress inducing situations (Monestier *et al.*, 2015). Because the fawn is heavily dependent on its mother during the first months of its life, how a doe copes with challenging situations directly influence the survival of her fawns. This tie between doe behavior and fawn survival may not be linear in nature, but has previously been shown to vary depending upon the habitat in which the doe lives. For example, Monestier et al. (2015) found that fawns with proactive mothers survived better in an open landscape, whereas fawns with reactive mothers had a higher survival rate in habitats with more cover.

Habitat also greatly influences fawn survival independant of mother behaviour. The selection of bed sites is a crucial defensive mechanism (Aanes and Andersen, 1996). Firstly, the amount of cover is of prime importance, since fawns are very subceptible to cold and wet weather (Kjellander *et al.*, 2012). Secondly, bed site selection is important for concealment to avoid predators (Aanes and Andersen, 1996; Linnell *et al.*, 1999). Lastly, proximity of the bed site to habitat edges and high light penetration, which provide food avaliblity and aid in thermoregulation respectivly (Van Moorter *et al.*, 2009).

By selecting these habitats with a higher density of food, a doe’s foraging efforts will be shorter and more successful, giving her the option to spend more time protecting her fawn. But there also exists a positive correlation between the quality of the habitats food resources, and the risk of predation (Panzacchi *et al.*, 2009). Indeed, in the case of roe deer, the reproductive success of mothers within areas of higher food density has only been found to exceed that of lower quality habitats in years when predator density has been low (Kjellander *et al.*, 2004). This indicates that choice of a more resource abundant habitat is not a strive for the best possible area to inhabit, but rather a trade-off between resource availiability and predation risk.

This variety of dangers, the fawn’s early reliance on its mother, and a disproportionately high mortality among fawns lead to a major constraint on the roe deer population. As such, identifying and quantifying the exact factors that control these mortality causes leads to a greater understanding of the dynamics of roe deer survival patterns.

1.5 The Study

In this study we chose to focus on behavioral characteristics tied to the mother, followed by characteristics tied to mother quality (Tab. 1). We also added characteristics tied to the fawn's quality and behavior, as well as certain abiotic factors. Lastly, fundamental to this study was the mortality of the roe deer fawns. Since roe deer fawns lay hidden for the first 1-2 months of life before they start to follow their mother (Andersen *et al*., 1998), it is during this time that the mother's vigilance should show the most pronounced effect. Therefore, only mortality that occurred during the first 60 days of life was included.

As mentioned, the mother's presence acts as deterrent to certain predators (Jarnemo, 2004)As such, how the doe positions herself spatially in relation to her fawn ought to be an important indication of the doe's level of vigilance towards her fawn. In addition, the doe's movement patterns, such as daily average movement (DAM), could be another important reflection of the doe's protective behavior during the fawning season.

An important parameter is also how the doe may react to stress and adverse situation as opposed to another doe. For this, we included an ordinal handling (H)- and release (S) score, reflecting how a caught doe acts upon capture and release. This was included as another measure of vigilance. Similarly, another ordinal scale of Doe Boldness Index was also incorporated. A mother that exuded a copious amount of stress-related behavior upon capture could likely be assumed to approach other aspects of life with a more vigilant and cautious personality. Whereas a doe that exuded a calmer air during a stress–inducing situation such as capture, could well be expected to act in a bolder, less tentative manner. It is possible that a bolder doe may act with disregard for the safety of their fawn, whereas a more vigilant one would act more protectively.

We also chose to analyze blood cortisol content in the caught individuals. Cortisol is a steroid hormone that is released at various levels in relation to stress, so as to increase glucogenesis and increase the body's blood sugar levels (Sand Olav *et al*., 2004). This provides the body with a burst increase in energy availability. Because of this, cortisol levels within the blood upon capture could provide a measure of how the body of any particular doe responds to dangerous situations (Beaulieu-Mccoy *et al.*, 2017). It was deduced that such levels could be indicative of how a certain doe could be expected to react to stressful situations, and thus act a measure of vigilance to danger.

In regards to doe quality, the age of the doe upon birth of the fawn was chosen, as well as the body mass of the doe. This provides an indicative of the quality of the mother at the time, and a mother of higher quality and more experience should stand a greater chance of managing her energetic constraints and trade-offs to a higher degree than a smaller and less experienced mother, as such increasing the survival chances of her offspring.

We also included factors tied to fawn quality, including fawn weight and temperature upon capture. Weight is an indication of health and quality, and divergence in temperature may well indicate the presence of disease. In addition, the number of tics found upon the fawn, as these act as vectors for disease and infection. Lastly, both cortisol levels and the movement patterns (DAM) were included. Cortisol, just as in the case of the mother, provides a measure of the fawn's reaction to stress, and as such an indicative of behavior. While the mothers cortisol may be construed as an indication of how protective or dismissive she may be in the face of danger, a fawns level of vigilance may indicate to what extent the fawn will prioritize remaining stationary, silent and hidden, opposed to mobile and exposed. Movement patterns also provide hints so as to this type of behavior.

Abiotic factors included the year of birth, which could indicate annual fluctuations in resources and uncovered conditions as affecting fawn survival. Average temperatures and precipitation both work as vectors of disease, and availability of food. More adverse abiotic conditions and lower food availability may force a mother to spend more time foraging, and as such, more time away from her fawn, leaving it vulnerable to predation. Site of capture also includes any between-site variations that may occur. Lastly, an index of roe deer density provides a measure of possible density dependent effects on fawn survival.

The purpose of this study was to examine what physical, physiological and behavioral characteristics exhibited by the doe and fawn that directly affect fawn survival during the first two months of life. To achieve this, we decided to construct a series of linear regression models, where the variables would be included in different constellations and tested against the mortality of the fawns. The models would then calculate which variables had a higher impact on mortality than the null model. The initial predictions were that fawn survival will be increased in; I) Does that exhibit higher levels of blood cortisol, II) Does that stay spatially closer to their fawns, III) Does that exhibit higher stress during trying situations i.e., capture and handling, IV) Does with a higher physiological quality, V) Fawns with a higher physiological quality, and VI) areas and time periods with mild abiotic conditions.

1.6 Study Area

The Swedish University of Agriculture has since 1974 conducted thorough monitoring of the roe deer populations in the areas of Grimsö, and since 1987 at Bogesund. Grimsö is an area located in the northern part of Västmanland in the southern central half of Sweden (59°40′ N, 15°25′ E) with an elevation of 113 meters above sea level. Being inland, the area often experiences harsh winters, with temperatures normally ranging between -20 °C during the winter and up to 25 °C during the summer, and with an annual average precipitation of 670 mm. Because of this, the forests fall on the border between boreonemoral and true boreal forest. In Grimsö both red fox, lynx and grey wolf *(Canis lupus)* prey upon roe deer. Estimates suggest an average of 2.44± 0.65 lynx family groups/1.000 km^2 at Grimsö between 1994 and 2006, and an average of 4.00±2.73 individual wolves in the area between 2003 and 2010 (Davies *et.al*, 2016). Bogesund is located to the immediate northwest of Stockholm, within

Figure 1: A Roe deer fawn being fitted with a GPS-tracking device at Grimsö.

Stockholm County (59°40′ N, 18°25′ E), close to the east coast of south central Sweden, at an elevation of only 6 meters above sea level. As a coastal area, Bogesund is more temperate than the inland area of Grimsö with a yearly average temperature of 7.7°C versus Grimsö's 6.5°C. The forest is also far more deciduous in character, being situated firmly within the borenemoral zone. Being costal, the temperature variations at Bogesund are usually smaller in amplitude than those of Grimsö. The sole predator of roe deer in Bogesund is red foxes, which only preys on fawns.

In both areas, predation by red fox is an important mortality factor for fawns. In Bogesund, the adult population is also heavily regulated by human harvest (Davies *et.al*, 2016). At Grimsö, harvest is minimal, and so predation by lynx is an important regulating factor (Davies *et.al*, 2016).

While monitoring of roe deer within these two areas has been constant since its beginning, the coalition of collected data types has varied throughout the years, with a wider array of variables such as cortisol samples and GPS-positioning were collected as time passes and technology progresses.

2.0 Method

The variables used in the study were collected over a wide span of continuous monitoring and capture of roe deer in the area of Grimsö and Bogesund, starting from 1987 and continuing until the present. Variables tied directly to fawns and does were collected during capture, visual monitoring, as well as GPS- and VHF monitoring. Abiotic variables such as precipitation and temperature were collected from local weather monitoring stations.

Table 1: A summary of all basic variables included in the analysis and the motivation for their inclusion.

Variable	Indication of:
Age of the Doe	Mothers physiological quality
Distance from Mother to Fawn (GPS)	Mothers vigilance towards her fawn
Distance from Mother to Fawn (VHF)	Mothers vigilance towards her fawn
Doe Boldness Index	Mothers vigilance towards her fawn
Doe Weight	Mothers physiological quality
Fawn Cortisol	Fawns vigilance
Fawn Daily Avarage Movement (DAM)	Fawns vigilance and quality
Mother Daily Avarage Movement (DAM)	Mother quality and vigilance towards her fawn
Fawn weight	Fawns physiological quality
Handling Score (H-Score)	How the mother reacts to stress-induction and measure of vigilance
Release Score (S-Score)	How the mother reacts to stress-induction and measure of vigilance
Mean Annual Precipitation	Disease among fawns and food availiability
Mean Annual Temperature	Disease among fawns and food availiability
Mother Cortisol	Mother vigilance
Fawn Temperature	Fawn physiological quality
Number of Ticks	Disease among fawns and fawn quality
Roe Index	Density dependant factors
Site	Site-specific variables
Year	Annual fluctuations

2.1 Capture

Capture is conducted during winter and early spring, for as long as the snow cover holds. During this time, the scarcity of food makes the roe deer more attracted to the traps. Capture is conducted in box traps, constructed with masonite boards and oil-treated wooden planks. The minimum size of these box traps are 1300x625x1300 mm. The box traps are baited with food pellets. The trapping mechanism consists of a line of fishing line, stretching from ceiling down to the floor of the trap, in the middle of the baited food pile. When an animal touches the fishing line, a pin connected to the line is removed, and a trap door at the opposite end of the trap slides down to incarcerate the individual. Baiting is conducted in the late afternoon, and emptying of the traps is done the following morning between 08:00 and 10:00.

In the case of a captured roe deer, the individual is often subdued using three people. One straddles the deer's body, while two others hold down deer's legs to prevent it from kicking. No sedation was used during handling. The individual was then marked with a serial number tag in its ear to identify it. The age of the individual was then assessed by assessing the amount of wear upon its teeth, as well as teeth eruption. Several measurements pertaining to body size was then taken. Blood samples were then taken from the main jugular vein running down the throat, and the individual is fitted with a tracking collar, either VHF or GPS. Lastly, the individual was weighed by tying its ankles together with a loop of rope and hanging it from a scale. Assuming everything went according to plan, the handling process took no more than 2-3 minutes in total.

2.2 Variable processing

The dataset was constructed based upon fawn ID-numbers. Each row constituted a unique fawn. Each column constituted a variable, with each cell containing the variable value unique either directly to the fawn, the fawn's mother, or the conditions during the fawns fawning period, depending upon the nature of the variable. Mortality was introduced in a binary format, depending on whether the fawn died (1) or survived (0) for 60 days after the estimated birth.

Physiological variables tied to fawn and doe quality, such as: doe and fawn total live body mass (kg), doe age (years), fawn body temperature (C°), average precipitation (mm) and average temperature (C°), doe boldness index, number of tics (tics/fawn) and yearly roe deer density index (Ind/km^2) were introduced unprocessed into the dataset.

Blood cortisol, handling & release scores, daily average movement, distance between mother and fawn demanded more thorough processing before being introduced in the dataset.

Since 2011, blood samples have been taken on all captured individuals in the Grimsö area. These blood samples were analyzed at the veterinary institute at the Swedish University of Agriculture in Uppsala to extract cortisol content. This data was incorporated by transforming the cortisol values into residual data to account for the number of captures per year, as well as years of repeated capture. This was to compensate for possible habituation effects that may be present in regards to cortisol levels exhibited during repeated capture. This was done by calculating the difference between each individual and the average of the total values for either doe or fawns. In addition, the average values and first measured values for each individual were also included.

Beginning in 2004, two index scales of behaviour during capture have been used for all captures made in the Grimsö area in an attempt to measure the behaviour and stress of each individual. The Handling Scale (H-scale) constitutes of values from 0-4, and describes how an individual behaves during handling, mainly in regards to level of struggle, such as kicking and screaming. The Release Scale (S-scale) constitutes of values from 0-2, and describes how an individual acts once it has been set free, mainly in regards to exhibited stress and flee pattern. For specifics in how these scales were rated (Table 2). These values were all denoted by the same person (Lars Jäderberg) throughout all observations. The same method has been used for several other studies in the Grimsö research area, and is not unique to this study (Bergvall et al., 2017). As with the aforementioned cortisol data, these indices were converted to residual values so as to account for habituation during repeated captures. In addition, both average and first recorded values for any given individual were also included.

Table 2: The different levels of the H and S handling- and release scores, and their criteria.

	Behaviour During Handling	Behaviour When Released
0	Calm. No resistance, no kicking, no screaming.	Leaves the area slowly. Stops several times.
1	Calm. Almost no screaming, kicks no more than roughly twice.	Runs away, but stops after a short distance.
2	Some screaming and kicking, but otherwise calm.	Runs away without stopping until it cannot be seen.
3	Stressed. Screaming and kicking to a greater degree, but the animal can be handled.	
4	Exceedingly stressed. The animal continuously kicks and screams. Almost impossible to handle or take measurements.	

VHF and GPS positioning collection using collars have been used in both the Grimsö and Bogesund area since 2005 and 2013 respectively. This information was used to calculate the average daily movement of both fawn and doe during the time interval of interest. GPS and VHF positioning of fawn and doe was also used to estimate the average and greatest distance between mother and fawn during the time period. All fawn positions were taken using VHF, due to the weight of GPS-collars. These measurements were taken once a day during the fawns first 60 days of life. Doe positions were taken using both VHF and GPS collars. Doe positions using VHF were taken sporadically, sometimes as far apart as several days.

Daily average movement (DAM, Meters/24 hours) was only done using GPS data for the doe, and VHF for the fawn. VHF positions for the doe were deemed far too sporadic to be of use. DAM was calculated by selecting one location per individual for each day. Only locations recorded within the first 60 days of life, or shorter if the equivalent fawn died earlier, were selected. Daily movement was estimated by measuring the spatial distance using ArcGIS between two points during two consecutive days. Estimating daily movement was then a simple task of averaging this distance over the time between the positions.

Calculation of spatial distance between mother and fawn (Meters) was split into both GPS and VHF originating data for the does. Here, the positions of the mother was selected based upon as close a temporal proximity to the time of the fawns recording as possible, but not outside a time span of ± 3.5 hours of the fawns recorded position. For each such paired position, the spatial distance between the two was measured using ArcGIS. The average value was obtained adding the total distance of all paired measurements, and dividing by number of measurements. Greatest distance was included as simply selecting the greatest distance measured between any given fawn-doe pairing.

Mortality data has been collected throughout the entire monitoring process, and is well documented as far back as 1987. This data was introduced to ascertain if a fawn had died somewhere between its birth in late may to early June, and the first of august of the same year, resulting in an average 60 days time span. Mortality was binary, with 0 = Fawn died within 60 days, and 1 = Fawn survived for > 60 days. Cause of mortality was also included, so as to guard against types of mortality that could not be expected to share causality with either fawn or doe related variables, such as mowing. Predation was also split into two sub-categories, fox predation and predation caused by other predators. The reason for this was due to the fact that the overwhelming amount of predation on young fawns in these two areas is caused by red foxes, particularly in Bogesund, were other large predators are absent. Grouping the two together may therefore cause either group to mask the other in regards to variable causality, since the doe may for example be able to protect their fawns from foxes, but not from larger predators such as wolf and lynx, although these are present only within Grimsö research area, and not within the Bogesund research area.

2.3 Model Construction

The variables were then introduced into a correlation matrix. Greatly correlated variables being inherently misleading when introduced together in a statistical model, variables with correlations with a P-value exceeding 0.05 were not included in the same model.

The purpose of the constructed model was to identify the variables that best explained patterns of mortality in the roe deer fawns. As such, all models included the binary fawn mortality data as its response variable, in addition to two or more explanatory variables (Age, Cortisol levels, H-Score etc, see Table 1). The null model was defined as the explanatory variables having no effect on fawn mortality.

The model used to incorporate the variables was a logistic regression model, constructed in R-Studio (The R Project for Statistical Computing). Three parameters were then used to evaluate each model and its likelihood of fit compared to the null model: Weighted logistic regression, delta method and logarithmic likelihood of fit. Initially, all uncorrelated explanatory variables where introduced in all possible combinations of two into the model, and evaluated against the null model based upon delta weight and logarithmic likelihood. The results of these simpler models were used to identify the variables that bested the null model using the parameters.

The next step was to include all explanatory variables that defeated the null model in more complex combinations. Evaluating the results of these advanced models allowed for the construction of three final models, two containing factors tied to the mother, and one containing factors tied to the fawn. These models were evaluated in the same way as previously described.

3.0 Results

In total, 511 fawns were included. Of these, 371 had identified mothers. 146 does constituted the mothers to these fawns. Of these 511 fawns, 161 were recorded as dead within the allotted 2 month period. Of the 371 pairings of mother and fawn, 24 had identifiable and comparable GPS- and VHF locations during the 2 month period. 19 of the doe's and 49 of the fawns had recoded cortisol values. 31 of the does had recorded handling and release scores.

3.1 Model 1: Fawns.

The first model included the fawn's daily average movement (DAM), the fawn's residual cortisol values and the level of precipitation for the given period. In this model, none of the variables, or combination thereof, successfully managed to provide a higher explanatory power than that of the null model (Table 33). The null model parameters (Weight = 0.36, Δ = 0, Logarithmic Likelihood = -16.4) collectively outweighed those of all combinations of explanatory variables.

Table 3: Model outcome based fawns residual cortisol levels (Cortisol), precipitation and fawn daily average movements (DAM) in relation to fawn survival during the first 60 days in life. Df = degrees of freedom, Weigh = Weighted Logistic Regression, Δ = Delta Weight, LogLik = Logarithmic Likelihood of fit. Data is based on 37 fawns captured during 2013 – 2017 in south central Sweden. No combination of variables bested the null model in AIC.

Variable Combination	df	Weight	Δ	LogLik
Null Model	1	0.36	0	-16.4
Residual Cortisol	2	0.2	1.18	-15.87
Fawn DAM	2	0.13	2.06	-16.31
Precipitation	2	0.12	2.19	-16.38
Fawn DAM + Residual Cortisol	3	0.07	3.15	-15.67
Residual Cortisol + Precipitation	3	0.07	3.35	-15.77
Fawn DAM + Precipitation	3	0.04	4.41	-16.3
Fawn DAM + Residual Cortisol + Precipitation	4	0.02	5.48	-15.57

3.2 Model 2: Doe Movement, Handling & Release score.

The second model comprised of the first Handling (H)- and Release (S) values for captured behaviour that had been registered for an individual, along with the mean distance set between mother and fawn based upon GPS-data, and finally the doe's daily average movement (DAM) based upon the same GPS-data. The model was split into two sub-models, one for the H-values and one for the S-values. The two could not be included within the same model as they were correlated. An overview of fawn survival distribution based upon the mothers H- and S- values can be found in appendix 2 and 3.

The model containing S-values yielded positive results, with two combinations of explanatory variables beating the null model (Weight = 0.15, Delta = 1.72, Logarithmic Likelihood = -10.95). Mean distance between mother and fawn (Weight = 0.35, Delta = 0, Logarithmic Likelihood = -8.83) as well as mean distance in combination with first recorded S-value (Weight = 0.17, Delta = 1.43, Logarithmic Likelihood = -8.12) did so respectively (Table 4). It should however be noted that the S-value only won out over the null model when incorporated in combination with the mean distance variable. Alone, it failed to exceed the weight of the null model (Weight = 0.11, Delta = 2.21, Logarithmic Likelihood = -9.94). In addition, the mothers daily avarage movement failed to beat the null model in all configurations. The relationship between fawn survival probability and the mean distance between mother and fawn was negative (Figure 2).

Table 4: The results of the model containing the first recorded release score (S-Value), the mean distance between mother and fawn, as well as the doe's daily average movement (DAM). Df = degrees of freedom, Weigh = Weighted Logistic Regression, Δ = Delta Weight, LogLik = Logarithmic Likelihood of fit. Data is based on 19 does captured during 2013 – 2016 in south central Sweden. Mean Distance between mother and fawn as well as the S-Value bested the null model in AIC.

Variable Combination	df	Weight	Δ	LogLik
Mean Distance	2	0.35	0	-8.83
Mean Distance + First Release Score	3	0.17	1.43	-8.12
Null Model	1	0.15	1.72	-10.95
First Release Score	2	0.11	2.21	-9.94
Mean Distance + Doe DAM	3	0.08	2.83	-8.82
Doe DAM	2	0.07	3.21	-10.44
First Release Score + Doe DAM	3	0.04	4.43	-9.62
Mean Distance + First Release Score + Doe DAM	4	0.03	4.65	-8.1

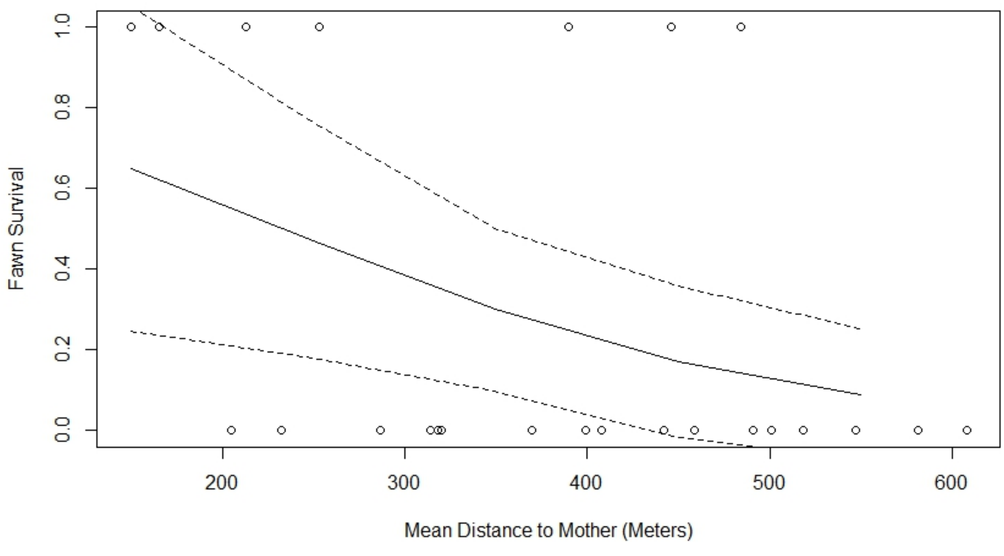

Figure 2: The relationship between Fawn survival (Y-axis, 0=Dead past 60 days, 1=Alive past 60 days) and the mean distance between mother and fawn (X-axis).

The model containing H-vaues also yeilded positive results, with both Mean Distance (Weight = 0.31, Delta= 0, Logarithmic Likelihood = -8.83), the H-value (Weight = 0.2, Delta = 0.84, Logarithmic Likelihood = -9.25) and the combination of the two value (Weight = 0.14, Delta = 1.53, Logarithmic Likelihood = -8.17) managing to best the null model (Table 5). Again, the doe's daily avarage movement failed in all configurations to best the null model.

Table 5: The results of the model containing the first recorded handling score (H-Value) of the mother, the mean distance between mother and fawn, as well as the doe's daily average movement (DAM). Df = degrees of freedom, Weigh = Weighted Logistic Regression, Δ = Delta Weight, LogLik = Logarithmic Likelihood of fit. Data is based on 19 does captured during 2013 – 2016 in south central Sweden. Mean Distance between mother and fawn as well as the H-Value bested the null model in AIC.

Variable Combination	df	Weight	Δ	LogLik
Mean Distance	2	0.31	0	-8.83
First Handling Score	2	0.2	0.84	-9.25
First Handling Score + Mean Distance	3	0.14	1.53	-8.17
Null Model	1	0.13	1.72	-10.95
Mean Distance + Doe DAM	3	0.07	2.83	-8.82
Doe DAM	2	0.06	3.21	-10.44
First Handling Score + Doe DAM	3	0.05	3.65	-9.23
Mean Distance + First Handling Score + Doe DAM	4	0.04	4.29	-7.92

3.3 Model 3: Doe Cortisol, Handling & Release score.

The third and final model incorporated two variables, namely the cortisol value recorded for the mothers first capture and the H- and S-value for behaviour upon handling and release. Again, this model was split in two, one for handling and one for release score.

The model containing the S-value yeilded positive results, with the S-vakye alone (Weight = 0.3, Delta = 0, Logarithmic Likelihood = -23.2) attaining a higher parameter score than the null model (Table 6). The cortisol values failed to best the null model in any configuration.

Table 6: The results of the model incorporating the first recorded release score (S-value) for the mother, as well as the first recorded cortisol sample for the mother. Df = degrees of freedom, Weight = Weighted Logistic Regression, Δ = Delta Weight, LogLik = Logarithmic Likelihood of fit. Data is based on 38 does captured during 2010 – 2016 in south central Sweden. Only the S-Value bested the null model.

Variable Combination	df	Weight	Δ	LogLik
First Release Score	2	0.3	0	-23.2
Null Model	1	0.28	0.18	-24.41
First Cortisol Sample	2	0.22	0.65	-23.53
First Release Score + First Cortisol Sample	3	0.2	0.8	-22.42

Finally, the model containing the H-value also yeilded positive results, with the H-value (Weight = 0.33, Delta = 0, Logarithmic Likelihood = -23.1) besting the null model (Table 7). Again, the cortisol values failed to best the null model in any configuration.

Table 7: The results of the model containing the first recorded H-value for the mother as well as the first recorded cortisol value for the mother. Df = degrees of freedom, Weight = Weighted Logistic Regression, Δ = Delta Weight, LogLik = Logarithmic Likelihood of fit. Data is based on 38 does captured during 2010 – 2016 in south central Sweden. Only the H-Value bested the null model.

Variable Combination	df	Weight	Δ	LogLik
First Handling Score	2	0.33	0	-23.1
Null Model	1	0.27	0.38	-24.41
First Cortisol Sample	2	0.22	0.85	-23.53
First Handling Score + First Cortisol Sample	3	0.18	1.27	-22.56

4.0 Discussion

In relation to prediction I, that fawn survival is increased for does that exhibit higher levels of cortisol, there was little real support. Prediction II, that fawn survival is increased for does that stay spatially closer to their fawns received a significant level of support. Prediction III, that fawn survival is increased for mothers that exhibit higher stress during trying situations such as handling showed a certain measure of support. Prediction IV, V and VI, that fawn survival is increased for fawns with a higher physiological fitness, with mothers with a higher physiological fitness, and in areas with milder abiotic conditions showed no support.

Both release score (S-Value), handling score (H-Value) and the average distance between doe and fawn resulted yielded positive results in the analysis, and were shown to exhibit a greater explanatory power of fawn mortality than would random chance. As such, evidence suggests that there is indeed a relationship between these variables and the chances of fawn survival.

4.1 Mean Distance between Mother and Fawn

Proximity to the mother has been proven by Jarnemo (2004) to severely limit the success rate of fox predation on the fawn, as the fox will either simply be dissuaded from attacking, or else the mother will protect her fawn from the predator. Because fox predation is a key factor to early fawn mortality and the doe plays a key role in preventing it, a reasonable conclusion is that a closer proximity to her fawn yields a higher fawn survival rate. The trade-off for this behavior would be that the mother worsens her own prospects of finding better sources of food. In addition, in areas such as the Grimsö research area, where larger predators are present, protecting her fawn may lead to a direct threat of predation for the mother as well. The fawn, being perhaps less prone to cryptic behavior than an adult, may well attract the attention of predators. In the case of larger predators, excessive protection of her fawn may thus increase the risk of harm to the mother.

It should be noted that the variable for the greatest distance between mother and fawn recorded for any given pairing was given only token inclusion in the analysis, because this variable exhibited an almost perfect explanatory value, regardless of the complexity of the model it was included in. In combination with the results from the average distance parameter, this could be considered to provide ample support to the hypotheses that the way a mother relates to her fawn on a spatial scale is a key component in fawn survival.

4.2 Mother Daily Average Movement

The mother's daily average movement (DAM) did not exhibit prevail against the null model when incorporated within the final models. However, during construction of early models containing only 2 variables at most, DAM showed a high degree of promise, consistently exceeding the null model in terms of weight, delta value and logarithmic likelihood. In the final model however, it fell behind when combined with other equally promising variables, like average distance between mother and fawn. In combination with the reality that there were relatively few posts of data that overlapped between this variable and several others, providing relatively weak statistical power, lead to these models being excluded from the study's results.

However, we would not say that there is no link between the daily movement patterns of the doe and fawn mortality. Instead, the reverse may well be true. Since there was a strong link between the average distance between the mother and fawn, and the survival rate of the fawn, it could be reasoned that there should also be a link between the mother's daily movement and fawn survival. There was shown to be no correlation between the doe's daily movement and the fawn's daily movement rate ($p \geq 0.5$) and as such, the mother's daily movement is another indication of how she positions herself to her fawn on a spatial scale. Although there also was no correlation found between the mothers DAM and the average distance between mother and fawn ($p \geq 0.1$), one could argue that they both work within similar domains of spatial social interaction between doe and fawn. Because of all these factors, it should be considered that a more detailed compilation of data points, with higher overlap needs to be collected before any definite conclusions can be made on the does DAM relationship with fawn mortality.

4.3 Release and Handling Scores

The release score (S-Value) and handling score (H-Value) provide a somewhat different challenge in interpretation. The score is an abstract value that is given to determine the behavior of the doe upon release after capture and handling, as a representation of its relative behavior and character when subjected to stress-inducing circumstances. Because of this, there is an obvious weakness with the scale; its subjectivity. During thise study, this scale was only used at Grimsö,but this subjectivity was negated by the fact that the score for all individuals included in this study, and indeed, all individuals ever measured with this scale, has been conducted by a single person, with clear definitions as to what kind of behavior characterizes the different levels of the scale. However, though a scale such as this is inherently subjective in nature, there is certain evidence that attests to its relative consistency and repeatability on individual level over time and as practiced by different people (Debeffe *et al.*, 2015). Because of this, the handling and release scale should work effectively for similar purposes regardless of area and practitioner.

H- and S-values repeatedly bested the null model, but with varying strength and consistency. The relationship between mortality and these values also varied. Because of this, no clear conclusions can be drawn from these results, other than how a mother acts according to these values seem to have some effect on fawn mortality, even if the nature of those effects are not definite.

4.4 Precipitation and Temperature

The lack of any abiotic effects such as precipitation besting the null model was initially surprising. According to Andersen & Linell (1998) an important factor in early fawn mortality is the onset of diseases such as pneumonia and hypothermia, which commonly originates from cold weather conditions and higher precipitation levels. Similarly, average and extreme temperature levels during the fawning period exhibited no explanatory effect on fawn mortality. However, at Bogesund and Grimsö direct climate effects has a relatively weak impact on roe deer survival as opposed to predation and harvest by humans (Davies *et.al,* 2016), so within these two areas the negligible effect of these variables is to be expected. Furthermore, the effect of climate may be masked due to the compensatory mortality of doomed animals by predation. Another explanation could be that some weather conditions may promote greater food resources, which balances mortality rate.

4.5 Cortisol

In the initial pair wise analysis the mother's cortisol values yielded promising results. However, although the later model yielded little support that this parameter contributed significantly to the likelihood of survival in the fawn, it is worth noting that the test sample of this particular parameter was constrained. This is due partly to the relative short amount of time that blood samples have been taken at Grimsö with testing cortisol levels in mind, but also due to the restricted number of individuals where this data has overlapped with other variables. We are therefore not comfortable in stating outright that the mothers stress levels as indicated by her cortisol levels has no link with the survival of her fawn.

There are two other factors that complicate the analysis of cortisol and its link between the mother and fawn survival. Firstly, it should be noted that the indication of stress levels is not cortisols sole function within the body. Cortisol levels also rise as an indication of low levels of blood-glucose in the blood (Sand *et.al,* 2004). Both this incitement, and the one tied to stress, is meant to increase the metabolic rate of fats, protein and carbohydrates, so as to provide the body with more energy at times of higher metabolic demands, such as during stressful periods and periods of low food intake (Sand *et.al,* 2004).

Secondly, cortisol varies naturally throughout the daily rhythm of an individual, and is closely tied to its sleeping patterns (Sand *et.al*, 2004). After periods of prolonged sleep, and hence low food intake, an individual's blood glucose levels are naturally low, and as such, its cortisol levels are naturally high. This level of cortisol then falls during the day (for diurnal organisms), mirroring the increase in blood glucose as a response of continued food intake. Because of this, any analysis of cortisol values need to take into account the time of sampling, as any given individual would have higher cortisol levels earlier in their daily rhythm as opposed to later. This would also be purely based upon natural fluctuations, and as such unrelated to its current stress levels. The fact that ruminants sleep very little in any given cycle, and for only short periods of time further complicates this matter. Food intake is relatively continuous as opposed to other animals. Because of this, the daily rythm of cortisol levels in roe deer may be lower in amplitude than would be expected. But without a closer study of the patterns of natural cortisol release within roe deer, no firm conclusions can be drawn from this yet.

Both of these factors strive to complicate the interpretation that the cortisol values measured in the doe's blood is an indicative of stress level. While we cannot comfortably refute that cortisol does not share a link with fawn survival, it may be presumptuous to assume that should such a link exist, that it be directly tied to the stress levels of the mother. Cortisol is a complex acting steroid hormone, and its effects on an individual should never be considered to be one-dimensional.

Lastly, there is one other factor that complicates the interpretation of cortisol values, which are the effects of habituation. Since many individuals around Grimsö are captured several times during the course of their lifespan, repeated exposure to the trials of capture may lessen the stress inducing effect caused by capture. This could naturally be combated by simply using the first cortisol values recorded for an individual, but this causes issues with the aforementioned reality of natural cortisol fluctuations, which in turn is most effectively combated by average or median values of repeated sampling. In the end, all of these different parameters were taken into consideration, and were all included as separate variables in the design of the models.

5.0 Conclusions

Firstly, this study provides strong evidence that there is a negative link between how far an individual doe positions herself in relation to her fawn on a spatial scale, and the chances of early survival for said fawn. Secondly, the study provides some evidence that there is a link between how an individual mother acts during stress inducing situations such as handling and capture and the survival of her fawns. By the definition adhered to in this study, evidence would therefore suggest that there is an effect of the doe's personality upon the survival of her fawn. And thirdly, this study provides inconclusive evidence that there is a positive link between the mother's cortisol levels as an indication of relative stress levels and the survival rate of those mothers' fawns. As this parameter showed promise, but the results were inconclusive, this study strongly suggests this parameter be tested further.

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8.0 Appendix

Appendix 1: Correlation matrix of variables. Coloured combinations indicate p-values <0.05.

Correlation Matrix	Year	Site	Fawn weight	Fawn Temperature	Mean Annual Temperature	Precipitation	Doe Weight	Age of Doe	Doe Boldness Index
Year	NA	0.0005	0.0264	0.2890	0.0288	0.2159	0.3043	0.4665	NA
Site	0.0005	NA	0.0429	0.3258	0.0000	0.0444	0.0000	0.1513	0.0013
Fawn weight	0.0264	0.0429	NA	0.0135	0.1860	0.6031	0.1697	0.4548	0.0798
Fawn Temperature	0.2890	0.3258	0.0135	NA	0.8891	0.2342	0.5873	0.4016	0.4762
Mean Annual Temperature	0.0288	0.0000	0.1860	0.8891	NA	0.4392	0.0988	0.2105	0.0013
Precipitation	0.2159	0.0444	0.6031	0.2342	0.4392	NA	0.2584	0.0647	0.0023
Doe Weight	0.3043	0.0000	0.1697	0.5873	0.0988	0.2584	NA	0.0000	0.1416
Age of Doe	0.4665	0.1513	0.4548	0.4016	0.2105	0.0647	0.0000	NA	0.2874
Doe Boldness Index	NA	0.0013	0.0798	0.4762	0.0013	0.0023	0.1416	0.2874	NA
Roe Deer Density Index	0.0000	0.0000	0.3341	0.5427	0.0000	0.3915	0.0000	0.1498	0.0013
Handling score (Same Year)	0.5312	0.9574	0.1579	0.4137	0.5239	0.6849	0.0212	0.8997	0.4927
Release Score (Same Year)	0.0706	0.0002	0.3639	0.4896	0.0014	0.2158	0.2939	0.9561	0.0002
Avarage Handling Score	0.0380	0.1870	0.4377	0.7557	0.4915	0.6988	0.0520	0.8699	0.8578
Avarage Release Score	0.2915	0.8182	0.2824	0.3472	0.6804	0.1505	0.0200	0.0643	0.0013
First Handling Score	0.0453	0.0138	0.7626	0.6407	0.3460	0.4779	0.2375	0.7734	0.9987
First Release Score	0.6382	0.3394	0.4451	0.5039	0.4219	0.2864	0.0421	0.0905	0.1954
Residual Handling Score	0.6933	0.9023	0.3733	0.0284	0.3243	0.9792	0.1217	0.6421	0.9336
Residual Release Score	0.0023	0.1227	0.8771	0.0842	0.4327	0.1005	0.6575	0.9843	0.0002
Greatest Distance to Mother(GPS)	0.1265	0.6037	0.3555	0.6372	0.3949	0.4553	0.2971	0.5623	0.0463
Mean Distance to Mother (GPS)	0.3628	0.3443	0.1854	0.2513	0.0689	0.9760	0.5335	0.7263	0.1751
Mean Distance to Mother (VHF)	0.3851	0.0000	0.0056	0.6775	0.2140	0.2549	0.2999	0.7474	0.1987
Greatest Distance to Mother (VHF)	0.2217	0.0054	0.0899	0.5283	0.8288	0.2385	0.3825	0.4176	0.2785
First Cortisol Sample (Fawn)	0.1805	0.8874	0.2257	0.6069	0.9802	0.0639	0.8175	0.5474	0.3608
Median Cortisol Sample (Fawn)	0.3362	0.6894	0.2557	0.9210	0.3889	0.1704	0.9661	0.2874	0.4636
First Cortisol Sample (Mother)	0.4649	0.4402	0.3744	0.2311	0.1239	0.1899	0.9970	0.1873	0.1732
Median Cortisol Sample (Mother)	0.4118	0.5212	0.3651	0.8013	0.0777	0.5777	0.4234	0.0770	0.1011
Residual Cortisol Sample (Mother)	0.0147	0.1111	0.1098	0.5917	0.1894	0.7938	0.6036	0.1273	0.0534
Fawn Daily Movement	0.0002	0.0028	0.0102	0.1356	0.0014	0.0693	0.2668	0.5564	0.4795
Mother Daily Movement	0.3702	0.3347	0.9087	0.9032	0.5119	0.2141	0.7911	0.0012	0.0521

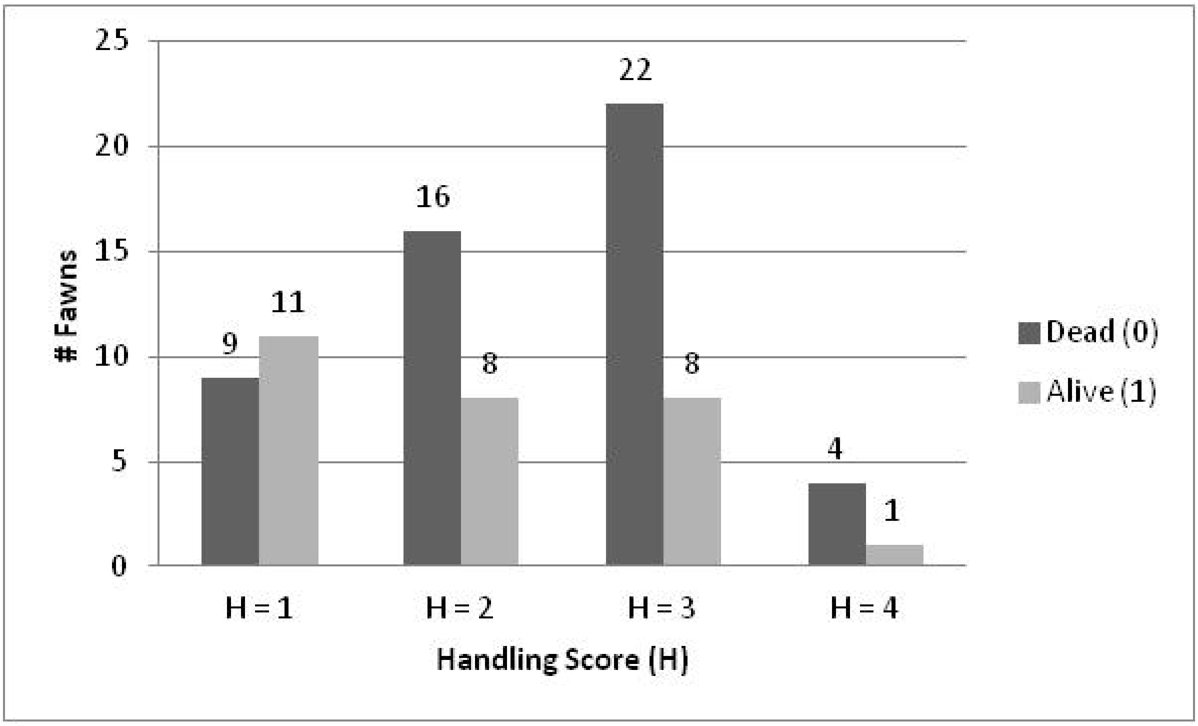
Correlation Matrix	Roe Deer Density Index	Handling score (Same Year)	Release Score (Same Year)	Avarage Handling Score	Avarage Release Score
Year	0.0000	0.5312	0.0706	0.0380	0.2915
Site	0.0000	0.9574	0.0002	0.1870	0.8182
Fawn weight	0.3341	0.1579	0.3639	0.4377	0.2824
Fawn Temperature	0.5427	0.4137	0.4896	0.7557	0.3472
Mean Annual Temperature	0.0000	0.5239	0.0014	0.4915	0.6804
Precipitation	0.3915	0.6849	0.2158	0.6988	0.1505
Doe Weight	0.0000	0.0212	0.2939	0.0520	0.0200
Age of Doe	0.1498	0.8997	0.9561	0.8699	0.0643
Doe Boldness Index	0.0013	0.4927	0.0002	0.8578	0.0013
Roe Deer Density Index	NA	0.1216	0.0042	0.7533	0.6777
Handling score (Same Year)	0.1216	NA	0.7199	0.0000	0.8415
Release Score (Same Year)	0.0042	0.7199	NA	0.1455	0.0000
Avarage Handling Score	0.7533	0.0000	0.1455	NA	0.4762
Avarage Release Score	0.6777	0.8415	0.0000	0.4762	NA
First Handling Score	0.3552	0.0000	0.0309	0.0000	0.4327
First Release Score	0.7507	0.0106	0.0000	0.0009	0.0000
Residual Handling Score	0.4452	0.0008	0.6052	0.0000	0.8020
Residual Release Score	0.1739	0.8006	0.0142	0.4622	0.0000
Greatest Distance to Mother(GPS)	0.2720	0.1791	0.6270	0.5109	0.1668
Mean Distance to Mother (GPS)	0.0665	0.7906	0.1931	0.9483	0.1114
Mean Distance to Mother (VHF)	0.0001	0.5464	0.2225	0.5717	0.8261
Greatest Distance to Mother (VHF)	0.0079	0.6501	0.6480	0.1445	0.5387
First Cortisol Sample (Fawn)	0.3010	0.5445	0.0234	0.3544	0.0658
Median Cortisol Sample (Fawn)	0.2408	0.4878	0.0245	0.4974	0.0570
First Cortisol Sample (Mother)	0.5116	0.6713	0.7829	0.7825	0.6007
Median Cortisol Sample (Mother)	0.5744	0.9292	0.8582	0.9001	0.2388
Residual Cortisol Sample (Mother)	0.3649	0.3689	0.0303	0.0588	0.0018
Fawn Daily Movement	0.0000	0.0716	0.5336	0.2210	0.4230
Mother Daily Movement	0.2851	0.9537	0.3280	0.7266	0.7487

Correlation Matrix	First Handling Score	First Release Score	Residual Handling Score	Residual Release Score	Greatest Distance to Mother(GPS)
Year	0.0453	0.6382	0.6933	0.0023	0.1265
Site	0.0138	0.3394	0.9023	0.1227	0.6037
Fawn weight	0.7626	0.4451	0.3733	0.8771	0.3555
Fawn Temperature	0.6407	0.5039	0.0284	0.0842	0.6372
Mean Annual Temperature	0.3460	0.4219	0.3243	0.4327	0.3949
Precipitation	0.4779	0.2864	0.9792	0.1005	0.4553
Doe Weight	0.2375	0.0421	0.1217	0.6575	0.2971
Age of Doe	0.7734	0.0905	0.6421	0.9843	0.5623
Doe Boldness Index	0.9987	0.1954	0.9336	0.0002	0.0463
Roe Deer Density Index	0.3552	0.7507	0.4452	0.1739	0.2720
Handling score (Same Year)	0.0000	0.0106	0.0008	0.8006	0.1791
Release Score (Same Year)	0.0309	0.0000	0.6052	0.0142	0.6270
Avarage Handling Score	0.0000	0.0009	0.0000	0.4622	0.5109
Avarage Release Score	0.4327	0.0000	0.8020	0.0000	0.1668
First Handling Score	NA	0.0000	0.0041	0.6729	0.6685
First Release Score	0.0000	NA	0.4458	0.2053	0.1866
Residual Handling Score	0.0041	0.4458	NA	0.0303	0.6759
Residual Release Score	0.6729	0.2053	0.0303	NA	0.7503
Greatest Distance to Mother(GPS)	0.6685	0.1866	0.6759	0.7503	NA
Mean Distance to Mother (GPS)	0.6151	0.3756	0.9805	0.9129	0.0002
Mean Distance to Mother (VHF)	0.3038	0.4295	0.3737	0.3009	0.0538
Greatest Distance to Mother (VHF)	0.0950	0.3223	0.2279	0.2282	0.0953
First Cortisol Sample (Fawn)	0.4611	0.1402	0.8322	0.0213	0.3676
Median Cortisol Sample (Fawn)	0.7198	0.0788	0.7728	0.0941	0.3397
First Cortisol Sample (Mother)	0.2814	0.8082	0.7918	0.0609	0.1801
Median Cortisol Sample (Mother)	0.4746	0.4372	0.4574	0.0579	0.1360
Residual Cortisol Sample (Mother)	0.3296	0.7165	0.3376	0.0031	0.3591
Fawn Daily Movement	0.6622	0.5239	0.2940	0.2623	0.6323
Mother Daily Movement	0.6930	0.5398	0.0711	0.2657	0.1407

Correlation Matrix	Mean Distance to Mother (VHF)	Greatest Distance to Mother (VHF)	First Cortisol Sample (Fawn)	Median Cortisol Sample (Fawn)
Year	0.3851	0.2217	0.1805	0.3362
Site	0.0000	0.0054	0.8874	0.6894
Fawn weight	0.0056	0.0899	0.2257	0.2557
Fawn Temperature	0.6775	0.5283	0.6069	0.9210
Mean Annual Temperature	0.2140	0.8288	0.9802	0.3889
Precipitation	0.2549	0.2385	0.0639	0.1704
Doe Weight	0.2999	0.3825	0.8175	0.9661
Age of Doe	0.7474	0.4176	0.5474	0.2874
Doe Boldness Index	0.1987	0.2785	0.3608	0.4636
Roe Deer Density Index	0.0001	0.0079	0.3010	0.2408
Handling score (Same Year)	0.5464	0.6501	0.5445	0.4878
Release Score (Same Year)	0.2225	0.6480	0.0234	0.0245
Avarage Handling Score	0.5717	0.1445	0.3544	0.4974
Avarage Release Score	0.8261	0.5387	0.0658	0.0570
First Handling Score	0.3038	0.0950	0.4611	0.7198
First Release Score	0.4295	0.3223	0.1402	0.0788
Residual Handling Score	0.3737	0.2279	0.8322	0.7728
Residual Release Score	0.3009	0.2282	0.0213	0.0941
Greatest Distance to Mother(GPS)	0.0538	0.0953	0.3676	0.3397
Mean Distance to Mother (GPS)	0.0988	0.1713	0.1265	0.0382
Mean Distance to Mother (VHF)	NA	0.0000	0.8356	0.8634
Greatest Distance to Mother (VHF)	0.0000	NA	0.5028	0.5270
First Cortisol Sample (Fawn)	0.8356	0.5028	NA	0.0000
Median Cortisol Sample (Fawn)	0.8634	0.5270	0.0000	NA
First Cortisol Sample (Mother)	0.5618	0.5912	0.6604	0.9471
Median Cortisol Sample (Mother)	0.4689	0.4806	0.8636	0.4680
Residual Cortisol Sample (Mother)	0.2975	0.3951	0.9895	0.8262
Fawn Daily Movement	0.0881	0.5528	0.8935	0.4749
Mother Daily Movement	0.4209	0.4960	0.2456	0.5946

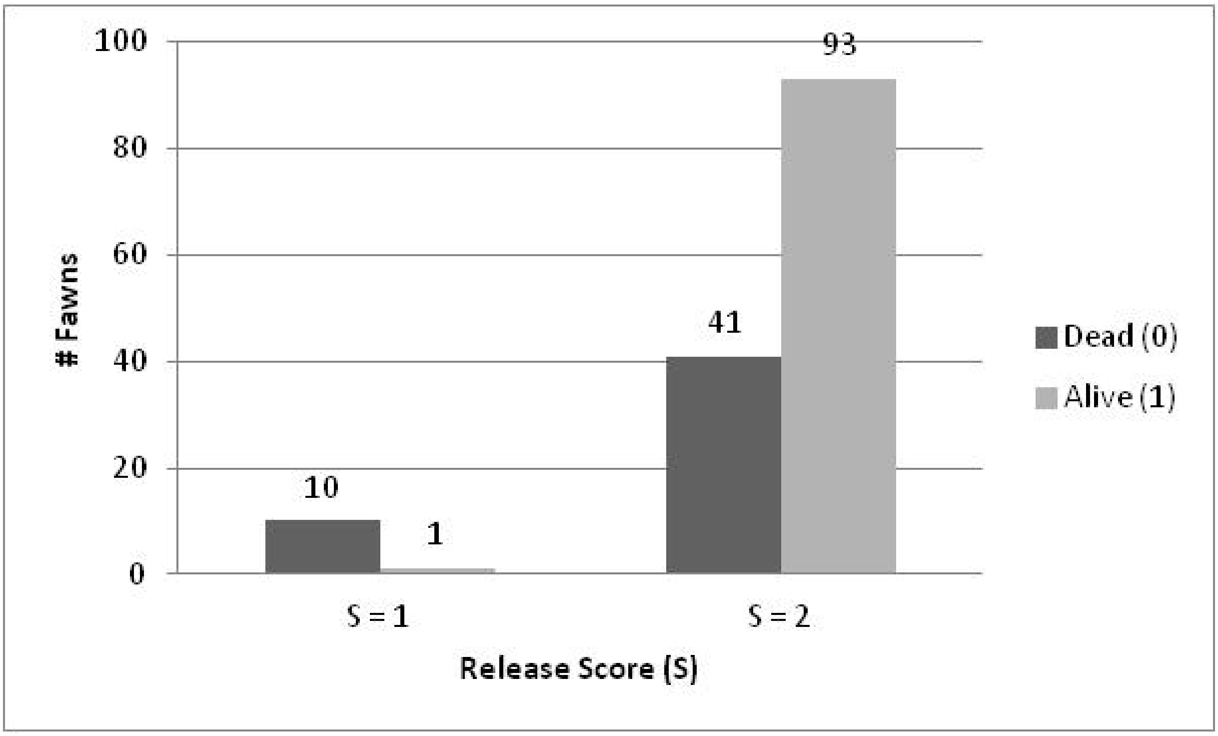
Correlation Matrix	Median Cortisol Sample (Mother)	Residual Cortisol Sample (Mother)	Fawn Daily Movement	Mother Daily Movement
Year	0.4118	0.0147	0.0002	0.3702
Site	0.5212	0.1111	0.0028	0.3347
Fawn weight	0.3651	0.1098	0.0102	0.9087
Fawn Temperature	0.8013	0.5917	0.1356	0.9032
Mean Annual Temperature	0.0777	0.1894	0.0014	0.5119
Precipitation	0.5777	0.7938	0.0693	0.2141
Doe Weight	0.4234	0.6036	0.2668	0.7911
Age of Doe	0.0770	0.1273	0.5564	0.0012
Doe Boldness Index	0.1011	0.0534	0.4795	0.0521
Roe Deer Density Index	0.5744	0.3649	0.0000	0.2851
Handling score (Same Year)	0.9292	0.3689	0.0716	0.9537
Release Score (Same Year)	0.8582	0.0303	0.5336	0.3280
Avarage Handling Score	0.9001	0.0588	0.2210	0.7266
Avarage Release Score	0.2388	0.0018	0.4230	0.7487
First Handling Score	0.4746	0.3296	0.6622	0.6930
First Release Score	0.4372	0.7165	0.5239	0.5398
Residual Handling Score	0.4574	0.3376	0.2940	0.0711
Residual Release Score	0.0579	0.0031	0.2623	0.2657
Greatest Distance to Mother(GPS)	0.1360	0.3591	0.6323	0.1407
Mean Distance to Mother (GPS)	0.9431	0.2030	0.0153	0.6704
Mean Distance to Mother (VHF)	0.4689	0.2975	0.0881	0.4209
Greatest Distance to Mother (VHF)	0.4806	0.3951	0.5528	0.4960
First Cortisol Sample (Fawn)	0.8636	0.9895	0.8935	0.2456
Median Cortisol Sample (Fawn)	0.4680	0.8262	0.4749	0.5946
First Cortisol Sample (Mother)	0.0000	0.0000	0.4278	0.1157
Median Cortisol Sample (Mother)	NA	0.0000	0.8120	0.1565
Residual Cortisol Sample (Mother)	0.0000	NA	0.5941	0.0763
Fawn Daily Movement	0.8120	0.5941	NA	0.5361
Mother Daily Movement	0.1565	0.0763	0.5361	NA

Appendix 2



Overview of distribution of fawns with mothers adhering to different handling scores (H-values).

Appendix 3



Overview of distribution of fawns with mothers adhering to different handling scores (H-values).