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Bovine and recreation interactions under semi-wild conditions:

Behavioural reaction of Tauros, European bison, Galloway and Scottish Highland cattle to three types of recreational visitors.

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Samenvatting

Begrazing door grote grazers (semi-wilde herbivoren, runderen, paarden) wordt in Nederland toegepast in natuurgebieden als beheersmaatregel om ongewenste vegetatie tegen te gaan en variatie in biodiversiteit in het landschap te behouden of te sturen. Door de toename van recreatie in natuurgebieden neemt ook de kans op interacties van mensen met semi-wilde herbivoren toe.

Voor natuurlijke, extensieve manieren van begrazing staan primitieve runderen en paarden die zelfstandig kalven en jaarrond in hun voedsel kunnen voorzien, steeds meer in de belangstelling. Zo is bijvoorbeeld in 2007 de Europese bizon of Wisent (*Bison bonasus*) als grote grazer geïntroduceerd in Nederland in het duinterrein het Kraansvlak te Noord-Holland. Een recente ontwikkeling in de zoektocht naar meer natuurlijke herbivoren is het Tauros-project, waarin geprobeerd wordt om door middel van een fokprogramma de uitgestorven Oeros weer terug te brengen. De komst van deze "nieuwe" grazers in het landschap roept vragen op met betrekking tot de veiligheid van recreanten in gebieden met "nieuwe" grazers. Momenteel bestaat er nog geen uitgebreid empirisch onderzoek naar de effecten van recreatie op het gedrag van grazers. Veel mensen weten niet hoe ze moeten reageren wanneer ze een kudde runderen tegenkomen in een natuurgebied. Dit illustreert de noodzaak voor het verstrekken van adequate informatie over rundergedrag, bijvoorbeeld: wat is de beste manier om te reageren wanneer je ineens wordt geconfronteerd met een kudde runderen, wat zijn tekenen van irritatie en wat zijn tekenen van nieuwsgierigheid?

Dit onderzoek maakt een vergelijking tussen verschillende runderrassen (Galloway, Schots Hooglandrund en het nieuwe ras Tauros) en de wilde runderachtige de Wisent in hun reactie op drie verschillende typen recreanten: een wandelaar, een wandelaar met een aangelijnde hond en een jogger. Om inzicht te verkrijgen in het gedrag van de verschillende runderen onder semi-wilde omstandigheden is gedragsonderzoek uitgevoerd door het simuleren van gestandaardiseerde interacties in het veld. Alle interactie simulaties zijn op video vastgelegd en later geanalyseerd.

Uit de resultaten blijkt dat opkijken de meest voorkomende eerste reactie was van de onderzochte runderen bij het waarnemen van een recreant, ongeacht het type recreant. Het tweede meest voorkomende getoonde gedrag was het typische kudde gedrag, hergroeperen met de andere leden van de kudde. Situaties waarbij de recreant door de runderen werd benaderd zijn slechts in 5% van de interacties waargenomen en betreffen vaak maar een deel van de kudde. Vooral jonge dieren zoals kalveren en jaarlingen bevinden zich in een belangrijke groei- en ontwikkelingsfase waarin ze veel leren door hun omgeving te verkennen. Hierdoor vertonen ze meer nieuwsgierig gedrag naar onbekende stimuli, zoals een recreant, wat de kans op benaderen vergroot. Bij geen van de gesimuleerde interacties zijn tekenen van agressie gericht op de recreant waargenomen.

Er zijn geen significante verschillen in gedrag tussen de verschillende runderrassen bij interacties met verschillende typen recreanten gevonden. De geteste runderrassen en de Wisent vertonen hetzelfde gedrag bij aanwezigheid van een wandelaar als bij een wandelaar met hond of een jogger. De aanwezigheid van een jogger zorgde er wel voor dat meer individuele dieren gingen lopen of rennen vergeleken met de twee typen wandelaars. In tegenstelling tot wat vaak wordt gedacht, reageren runderen dus niet anders op de een mens zonder of met een aangelijnde hond. Daarbij moet opgemerkt worden dat onze testhond een rustige, niet-blaffende noch grommende Schotse collie was. Een enkele aangelijnde hond wordt waarschijnlijk niet geassocieerd met hun

natuurlijke vijand de wolf. Voor het bepalen van de effecten op rundergedrag van meerdere honden, of van honden die reageren op de runderen door bijvoorbeeld te blaffen of te grommen, en van loslopende honden, is aanvullend onderzoek nodig.

Uit de resultaten blijkt dat het gedrag van de Tauros merendeels tussen de gedragsreacties van de gedomesticeerde runderrassen (Galloway, Schots Hooglandrund) en de wilde rundachtige de Wisent in valt. Tauros en Wisent reageren vanaf een grotere afstand (alert distance) op de aanwezigheid van een recreant en vertonen vaker een relatief sterke kudde reactie. Ook zijn Tauros en Wisent meer geneigd om zich te verplaatsen bij een interactie met een recreant dan de gedomesticeerde runderrassen (Galloway, Schots Hooglandrund).

Een aantal factoren was geassocieerd met verschillen in gedragsreacties van de runderen in de onderzoekspopulatie: ras, de structuur en omvang van het leefgebied, kudde grootte en de tijd op de dag van de interactie. Ras en tijd waren de sterkste invloeden, gevolgd door de structuur van het leefgebied. Het ras Tauros vertoonde de snelste en meest intense reacties, runderen reageren sneller en intenser later op de dag en gesloten (bebost) habitat was geassocieerd met snellere of intensere reacties.

Bij Tauros zijn verschillen tussen de individuele kuddes in gedragsreacties waargenomen. Deze zijn waarschijnlijk veroorzaakt door verschillen in de genetische samenstelling van de kuddes, de geschiedenis van de afzonderlijke leden van de kudde en mogelijke effecten van het fokprogramma zelf.

Meer onderzoek is nodig om de precieze invloed van zowel externe als interne factoren zoals rasverschillen te kunnen identificeren. Meer kennis van rundergedrag kan natuurorganisaties en beheerders helpen bij het maken van onderbouwde keuzes inzake het combineren van recreatie en begrazing door (primitieve) runderen.

Abstract

Grazing by different types of large herbivores in natural areas has been used as a nature management tool for directing vegetation succession and maintaining biodiversity. In the densely populated Netherlands, this implies that livestock grazing often co-exists with public recreation. The trend to allow for "natural" grazing has triggered an interest in more primitive and sturdy breeds that can be self-sufficient and so provide year-round grazing. For this purpose the European bison or Wisent *(Bison bonasus)* was introduced in the Netherlands in 2007. A recent development is the Tauros-project, that aims for re-creating the ancient Aurochs by means of an extensive breeding program. As human recreation in natural areas increases, so does the potential for interactions with semi-wild herbivores. With the use of more primitive, less domesticated herbivores in the landscape questions about public safety arise. The aim of the current study was to compare different cattle breeds (Galloway, Scottish Highland cattle and the new Tauros) and European bison for their reaction to three types of recreational visitors (walker, walker with a dog, jogger) in semi-wild conditions. To gain insight into the behavioural differences of bovine species, they have been tested by simulated interactions, using a standardized walker, jogger and walker with a dog on leash. All simulated interactions were documented on film and analysed afterwards.

The most common initial reaction of the investigated bovine species to a recreational visitor was to look up. The second most common initial reaction was to regroup with other herd members. Situations in which the recreational visitor was approached by cattle only occurred in 5% of the interactions and consisted of mostly calves and yearlings. They are in a highly explorative developmental stage thus increasing the chance of approach behaviour. In general, no differences in response between different types of recreational visitors were found. Only a jogger did cause more individual animals to start moving, either walking or running, compared to the other types of interactions. Bovine species did not react differently to the presence of a dog as compared to a walker without one.

Of the available factors in the data, breed, habitat cover and experiment time of day, had the strongest association with differences in behaviour. Tauros and Wisent had the fastest response time, longest response distance and most strong herd reactions. Generally, behavioural (herd) response was significantly stronger in covered habitat and later in the day.

Tauros behaviour was intermediate between that of Wisent and the domesticated cattle breeds. Both Tauros and the Wisent displayed a greater alert distance and showed more strong and severe herd reactions compared to the Galloway and Scottish highland cattle.

The Tauros herds showed between-herd differences in behavioural reactions. More research is needed to increase knowledge on behavioural reactions of different bovine species to recreational visitors and so aid natural resource managers in informed decision making.

Preface

This research has been commissioned by ARK Natuurontwikkeling in cooperation with the Taurus Foundation. It was conducted by the Copernicus Institute of Sustainable Development of Utrecht University to provide answers to questions asked by the public during the development and implementation of the Tauros project. The Tauros project is an initiative of the Taurus Foundation to recreate the extinct Aurochs using an extensive breeding program, developing a new and sturdy cattle breed that can be used as a natural large herbivore to maintain wilderness areas. Research was conducted by Janneke van Kessel MSc and supervised by Prof. Dr. M. J. Wassen. We thank Lennard Pisa for his valuable advices and support with the statistical analyses and we thank Lennard Pisa, Brian Dermody, Jiefei Mao, Koen Siteur, Floris van den Berg, Mara Baudena, Mart Verwijmeren, Mirjam Rentema, Marja van Steenbergen, Jerry van Dijk, Martin Wassen and Ellie van Kessel for volunteering as 'actors' during field tests.

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1. Introduction

Grazing by large herbivores (cattle, horses, deer) in natural areas has been used as a management tool against encroachment of unwanted vegetation (Kooijman and Smit 2001; Kohyani et al. 2008). Grazing by different types of herbivores is used as a common tool to maintain specific ecosystem characteristics, increase biodiversity and improve wildlife habitat. In the Netherlands, grazing by large herbivores often needs to co-exist with public recreation (Linnartz 2010).

As recreation in natural areas tends to increase, so does the potential for interactions with large herbivores. This raises questions about safety issues of public and large herbivore interaction. In the last 25 years, only a limited number of incidents between cattle and people have been documented (Linnartz 2010). Regarding the large numbers of recreational visitors of natural areas, this number is small, but public concern does exist. Potential conflict between large herbivores and recreational visitors of natural areas are especially worrisome to land managers. In some areas the public concern about possible conflicts may lead to reductions in public land grazing (Barry 2014). Public concern involves two elements: concern on what could possibly happen and lack of knowledge on how to respond when confronted a with (herds) of large herbivores (Barry 2014).

The trend to create more natural practices of managing herbivores in large natural areas has triggered an interest in using more primitive and self-sufficient cattle breeds. These breeds can calve outdoors with little assistance and show strong maternal behaviour. Part of this behaviour is strong defensiveness against predators (Turner and Lawrence 2007). Selection of behaviours that promote calf survival could however exacerbate the aggressiveness of cattle after calving (Turner and Lawrence 2007).

A recent development in the search for more self-sufficient herbivores is the Tauros-project, an attempt to bring back the ancient Aurochs by an extensive breeding program. The Aurochs went extinct as a wild species in 1627 (Goderie et al. 2013). Around thirty different European cattle breeds are included in the breeding program, for example: Lima, Maremmana Primitiva, Maronesa, Podolica, Sayaguesa and Pajuna (see table page 130 in Goderie et al. 2013). Al these breeds have different physical appearances and certain traits that are seen as desired Aurochs characteristics. Up to now, the Aurochs herds consist of different genetic cross-bred individuals with clear differences in exterior like size, coat colour, horn size and horn position. Herds tend to consist of individuals of mixed genetic make-up. Differences in genetic and husbandry backgrounds may influence behavioural reactions and result in differences between Tauros herds. Currently, several Aurochs herds are already grazing in natural areas in the Netherlands that are open to visitors.

Furthermore, endangered grazing species like the European bison or Wisent *(Bison bonasus)* were introduced into natural areas as part of a breeding program to increase their population and prevent extinction (Pucek et al. 2004; Baillie et al. 2004). In the Netherlands, Wisent were introduced in the Kraansvlak area in the Netherlands. Recently, this area has also been opened to the public for recreation.

The amount of literature on effects of anthropogenic activity like recreation on bovine or other ungulate behaviour is relatively limited. Bruggeman et al. (2007) studied the influence of winter recreation on American bison (*Bison bison*) and found that American bison readily use groomed roads, thereby tolerating and not interacting with recreational visitors. Coulon et al. (2010) found

that social structure of domesticated cattle depended strongly on their kinship. Stankowich (2008) reviewed available studies on flight response of ungulates. He found evidence that ungulates pay attention to approacher behaviour, have greater perceptions of risk when disturbed in open habitats, and females or groups with young offspring show greater flight responses than adult groups (see also (Mattiello et al. 2010). Increased group size had a weak positive (but heterogeneous) effect on flight response. Humans on foot were more evocative than other stimuli (vehicles, noises). Populations in areas with higher levels of human traffic showed reduced wariness but a lack of alternative sites to move to may explain some of this effect.

The alert distance (AD: distance at which the animal becomes alert) and flight distance (FD: distance at which an animal starts to act to escape) are quantitative variables that have been used as measurement of disturbance by different human activities. Taylor and Knight (2003) found that the alert distance and distance moved as a response of deer to off-trial recreationists were greater than deer responses to on-trail recreationists. American bison showed the shortest response distances compared to deer and other ungulates, with pronghorn (*Antilocapra americana*) showing the longest distances.

Effects of anthropogenic disturbances on energetic losses from flight, decreased foraging time, or increased stress levels come at costs for the individual energy recourses needed for survival, growth and reproductive success. Wildlife responding to disturbance by recreation can also negatively affect carrying capacity of wildlife habitat, with differences in response possibly attributed to differences in specific characteristics of each species (Taylor and Knight 2003). For example, it is speculated that American bison are rounded up or driven together annually and therefore are more tolerant to human disturbance than other species studied. Bison also have poorer eyesight compared to other ungulates and tend to stand their ground when facing a predator than taking flight (Hirth 2000, in Taylor and Knight 2003). It is difficult to make generalizations regarding the effect of human disturbance on wildlife responses because studies are conducted with a variety of methods. For example, some researchers approach wildlife directly others tangentially (indirectly, laterally).

Most of the current knowledge on cattle-human interaction is obtained from studies on the behaviour in domestic dairy and beef cows, such as the effects of human handling including early rearing and weaning effects on ease of handling animals later in life (Cooke et al. 2009; Hawke and Stewart 2012). Herd structure and social dominance, which is hypothesized to be linked to aggression, have been studied extensively in controlled farm settings. According to Murphey, Duarte and Torres Penedo (1981), domestic cattle have paradoxical tendencies both to approach and to avoid humans. Breed differences were evident for approach and avoidance behaviour which had little relationship to one another. Age of the individual took precedence over breed affiliation in investigating a human lying on the ground. A study by Šárová et al. (2013) demonstrated that age prevails over body mass in the structuring of the dominance in a herd of beef cattle. At the individual level the dominance of a cow was more strongly related to her age than her body mass. It was hypothesized that social dominance primary serves to reduce within-group aggression through ritualization (Šárová et al. 2013). But this may not hold for all beef cattle under all conditions. For instance, when unrelated same age beef calves are housed together in high density intensive feedlots, or when unrelated previous alien beef cows are grouped, body mass and personality have been found to be of more influence on resulting dominance than age differences (Landeata-Hernandez et al. 2013).

Although large herbivores have been used for at least two decades, no comprehensive examination of the effects of human disturbance on large herbivore behaviour under semi-wild conditions exists. This illustrates the need for adequate information on large herbivore behaviour; what are signs of aggression, what are signs of curiosity and how best to respond when facing an encounter. This study addresses this knowledge gap, focusing on various breeds of cattle and the Wisent.

1.1 Research aim

The aim of this study is to compare different cattle breeds and Wisent (*Bison bonasus*) in their reaction to three types of recreational visitors in semi-wild conditions, in order to evaluate the behaviour of the newly created Tauros breed. The types of recreational visitors of interest are the most common forms of recreation in natural areas; a walker, a walker with a dog and a jogger. The presence of a dog is of special interest because it is assumed that bovine species perceive dogs as their natural predator the wolf. Dogs may evoke a different kind of behavioural reaction and perhaps increase aggression.

It has been shown that American bison (*Bison bison*) and cattle differed in all behaviours (grazing, standing, bedded, moving, other) (Kohl et al. 2013). The Wisent can be compared to cattle (*Bos taurus*) because they are within the same family (Bovidae) and the two species are closely related. However, the different cattle breeds are domesticated animals, while Wisent remain wild.

Part of the goal of the current research is to increase knowledge on cattle behaviour under semi-wild conditions and to compare with behaviour of Wisent. This comparison also allows us to assess if Wisent or the new Tauros breed and recreational visitors can safely co-exist in the Netherlands.

To realize this aim it is necessary to gain more insight into the different factors (herd size, weather, time of day, breed, age, herd social structure etc.) influencing the behavioural reactions of bovine species when encountering recreational visitors. A better understanding of the effect of these different variables may aid to the formulation of recommendations on how to interpret bovine behaviour and educate both land managers and the public how to behave when encountering semi-wild cattle in natural areas.

1.2 Primary research questions

Is there a difference between Tauros, Galloway, Scottish Highland cattle and Wisent in their response to a walker, walker with a dog and jogger under semi-wild conditions? What factors influence the response of these bovine species to different types of recreational visitors and can we estimate their relative importance?

1.3 Secondary research questions

The main research questions have been divided into secondary research questions that can be answered by statistical analysis:

1. What are the differences in response of bovine species (all breeds together) to three types of recreational visitors: a walker, walker with a dog and a jogger?
    1.1. Does the **type of reaction** of a herd differ when encountering different types of recreational visitors?

1.2. Does **severity of the reaction** of a herd differ when encountering different types of recreational visitors?

1.3. Is there a difference in **who reacts first**; male, female or youngster to different types of recreational visitors?

1.4. Is there a difference in the **distance** to the herd when the first reaction occurs (alert distance) when encountering different types of recreational visitors?

1.5. Is **reaction-time of the first individual** of a herd different between different types of recreational visitors?

1.6. Is **speed of** the reaction different between different types of recreational visitors?

1.7. Is type **of behavioural reaction of the first individual**, associated with **the severity** of the herd reaction?

2. Can we identify external factors that influence the behavioural reaction of bovine species to different types of recreational visitors?

2.1. Does **breed** influence the reaction of bovine species?

2.2. Does **habitat** influence the reaction of bovine species?

2.3. Does **time of day** influence the reaction of bovine species?

2.4. Does **herd size** influence the reaction of bovine species (type of reaction, speed, severity, time and distance)?

3. What is the relative importance of different factors influencing bovine behaviour?

4. Are there differences in response between Tauros herds to three types of recreational visitors; a walker, walker with a dog and a jogger?

2. Methods

2.1 Research areas and species

Research was conducted in five different research areas: Kempen-Broek, Keent, Stadswaard, Herperduin and Kraansvlak (table 1). We documented and analysed the behaviour of two different bovine species. Cattle (*Bos taurus*) that are commonly used as feral grazers, Galloway, Scottish Highland cattle, the new breed Tauros and the wild bovine European bison or Wisent (*Bison bonasus*).

The research areas needed to satisfy the following criteria: easy accessible and open to recreational visitors, containing preferably several separate herds of the bovine species of interest. Five Tauros herds and two Scottish highland cattle herds were included in an attempt to eliminate herd specific differences as much as possible. Because the "back"-breeding program of the Aurochs is still an ongoing process, the existing Tauros herds consist of different crossbred individuals (F1, F2, F3 and counting genetic generations) in the same herds. Thereto, large differences in exterior and genetic background are present in the current herds possibly influencing the behavioural reactions. In order to eliminate this effect as much as possible, all five Tauros herds have been grouped for analysis and are assumed to be a good general representation of the new breed Tauros. Due to practical constraints only one Galloway and Wisent herd (the one existing herd in the Netherlands) could be included into the research.

Table 1: An overview of the research areas, their corresponding size and specific bovine species included in the research.

Research area	Habitat size (ha)	Species or breed
Kempen-Broek		
Loozerheide	120	Tauros
Siendonck West	22	Tauros
Tungelrooyse Beek	54	Tauros
Grauss	13,1	Tauros
Keent	330	Scottish Highland cattle
		Tauros
Stadswaard	120	Galloway
Herperduin	400	Scottish Highland cattle
Kraansvlak	280	Wisent

2.2 Interaction simulation

Behaviour of different cattle breeds and Wisent was investigated by simulated recreational visitor interactions. All simulation tests were carried out by volunteers under the supervision of the same permanent investigator (J.A.M. van Kessel MSc.). Volunteers were instructed and trained prior to entering the research areas.

Prior to behavioural testing

Before starting an interaction test, herd behaviour was observed for at least 20 minutes from outside the research area or at a minimum distance of 200 meters. If within these 20 minutes agitated or abnormal behaviour was detected, the herd was excluded from testing until normal natural behaviour was observed.

A minor degree of disturbance caused by day to day management was assumed to be the same for all herds. In the case of major disturbances, like the introduction of a new individual to the herd or removing an adult individual from an existing herd, the corresponding herd was temporarily excluded from the simulations until the social hierarchy had been reformed.

Types of recreational visitors

Three different types of recreational visitors; a walker, a walker with a dog, and jogger, were simulated in a standardized manner in order to test the behavioural response (see figure 1). The herd was never approached directly, but passed by the side in a steady straight line. The walker passed by at a steady pace of 1 step per second, making eye contact with the animals when they looked up at the recreational visitor. The jogger ran at a rate of 3 steps per second while passing a herd. For the interaction type: walker with a dog, the same well-trained dog was used (breed: Scottish Collie) for each simulated interaction. The dog showed no reaction (growling, barking, eye contact) to the presence of cattle or other bovine species to insure the test was repeatable in the same manner each time. A minimum approach distance of 25 meters to the herd was taken into account when testing the different cattle species and a minimum of 50 meters for testing the Wisent.

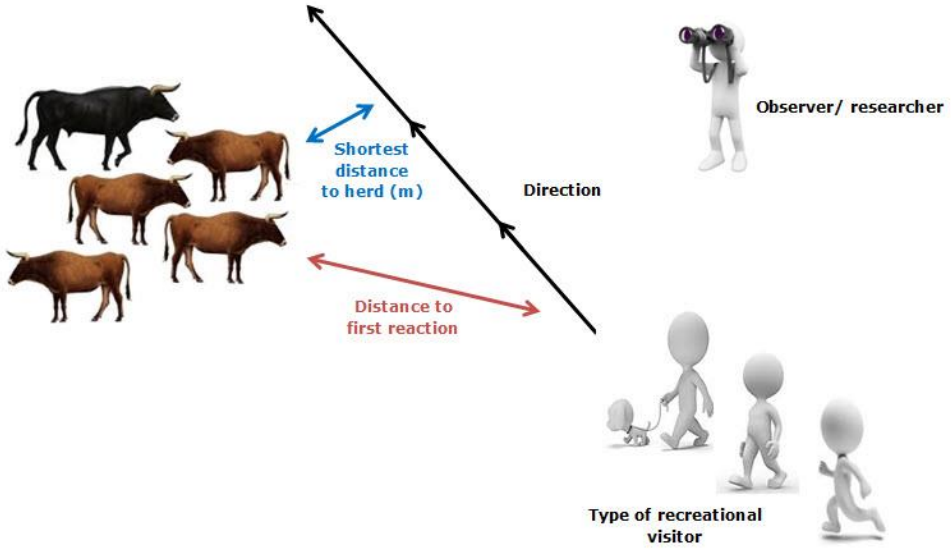

Figure1: Showing the experimental set-up of the interaction simulations: a walker, walker with a dog and a jogger.

For each simulation test the following variables were recorded:

Location, date, time of day, type of simulated interaction, breed and herd size. Group composition was noted by counting the amount of males, females and youngsters (from 0 to 1 year old calves) in a herd. Habitat vegetation structure was categorized in three groups: open, half-open and closed habitat. Open habitat consisted of mainly grassland, half-open habitat consisted of short growing herbaceous vegetation with scattered shrubs or few patches of trees and closed habitat consisted of vegetation dominated of trees and shrubs which posed an obstruction of view for the animals and recreational visitor.

Alert distance; the distance between the recreationist and the animals when they first become visibly alert to the recreationist (Taylor and Knight 2003; Stankowich 2008). The distance was measured using visual landscape cues to mark initial animal locations and estimated afterwards. The sex and estimated age of the individual that showed the first alert response. Also the response time (time of the first individual of a herd to respond to the visitor) was recorded.

The repeated sampling of herds and individuals could not be avoided since we only had a limited amount of herds available for our research (see also Taylor and Knight 2003; Rushen et al. 1999) However, we tried to avoid repeated sampling of a herd on the same day and to use randomized visits to different herds as much as possible.

2.3 Video analyses

All simulated interactions were recorded using a video camera (type Panasonic HC-V210) combined with notes taken in the field. The behaviours exhibited by the herd as a whole during the interaction as well as the behaviour of the first individual of the herd to react (the alert distance), were noted by the use of a constructed ethogram (table 2) (Leruste et al. 2013). The analysis of all video material was conducted by one observer to exclude observer bias due to differences in interpretation of the ethogram (Hawke and Stewart 2012; Murphey et al. 1981; Haskell et al. 2012). For testing, all initial behaviour was aggregated into six main groups representing directional information of the behaviour. Furthermore, the same initial behaviour was categorized

into three groups representing movement speed (walking, trotting, running) of the animal or herd during the interaction (for definitions of aggregated groups and speed see table 2).

Table 2 Ethogram used for (statistical) analysis of observed behaviour during testing. Definitions of initial behaviour are given and corresponding speed is depicted, including an aggregation of the different behaviours into six main groups.

Bovine behaviour interaction recreational visitors			
Aggregated behavioural groups	**Movement speed**	**Initial behaviour**	**Definition**
Observing	**Stationary**	**looking up**	Animal started looking at the recreational visitor
	Stationary	**Turning head**	Animal has head up and turns head to keep eyes on visitor, no movement of the body
	Stationary	**Looks up + moving**	Animal looks up at visitor and moves body around to keep eyes on visitor, no locational displacement
	Stationary	**stop and look**	Animal stops movement (walking, trotting, running) and looks into visitors direction
	Stationary	**rubbing**	Animal is rubbing against an object (tree, wooden bench etc.)
	Stationary	**standing**	Animal has head up and is standing, no directional movement
	Stationary	**laying down**	Animal has its whole body on the ground
Grazing	**Stationary**	**drinking**	Animal has head down and is drinking water
	Stationary	**stand + grazing**	Animal has head down and is grazing, no forward movement
	Walking	**Walk + grazing**	Animal is walking forward, has head down and is grazing
Getting up	**Stationary**	**getting up**	Animal gets up from a laying to a standing position
Approaching	**Walking**	**walking**	Animal walks in visitor direction
	running	**trotting**	Animal trots in visitor direction
	running	**running**	Animal runs in visitor direction
Avoidance	**Walking**	**walk away**	Animal walks in the opposite direction of the visitor
	running	**Trots away**	Animal trots in the opposite direction of the visitor
	running	**Run away**	Animal runs in the opposite direction of the visitor
re-group	**Walking**	**walking**	Animal walks towards other herd members
	running	**trotting**	Animal trots towards other herd members
	running	**running**	Animal runs towards other herd members

During video analysis the herd behaviour during the entire interaction simulation was categorized in five groups of reaction severity (definitions of severity see table 3). The severity category encompasses the entire behavioural response of the herd as a whole and allowed for more specific testing when dealing with a relatively small sample size.

Table 3 Categorisation and definition of herd behaviour into classes of severity of reaction.

Severity of herd reaction classification	
Severity category	**Definition**
None	No reaction of the herd. Individuals continue initial behaviour during the entire interaction; grazing, looking up, follow recreational visitor by moving head. No body movements, no displacement of herd individuals.
Mild	Looking up and moving body around to follow recreational visitor No displacement of herd individuals.
Medium	A maximum of 10 steps taken by a herd individual to re-group, approach or avoid. Steps are taken at walking speed only, no more than one displacement.
Strong	More than 10 steps are taken by a herd individual. Short displacement at trotting or running speed. More than one displacement during one interaction by the same individual
Severe	A very large displacement at running speed by most of the herd individuals. Herd individuals approach recreational visitor. All herd individuals run to avoid recreational visitor ending the interaction. Any display of aggression towards recreational visitor. Long recovery time.

2.4 Statistical analysis

Explanatory or independent variables are type of interaction (walker, walker with a dog, jogger), habitat cover type, habitat size, herd size and time of day. These independent variables were mainly of categorical nature. Continuous independent variables (time of day of the interaction, density of animals per hectare) tended to have very skewed distributions and were transformed to categories to avoid effects of rare extreme values. The dependent variables in the data consist of categorical (for example behavioural categories, see ethogram table 2) and continuous outcomes (reaction time and distance).

Categorical dependents were transformed to binary response variables, with a certain behavioural element compared to a reference category that included all other behaviour. In this way, an individual animal or herd scores positive or negative for a certain behaviour. Differences in the mean proportion of positive scores related to independent variables were analysed using logistic regression by means of a GLM (Generalized Linear Model) using a binomial error distribution and logit link function. Independent variables were first used in single factor models to determine their effect on the dependent variables. Factors that showed a (near)-significant effect versus the absence of this factor (intercept only model) were used together in multifactorial models to investigate their relative importance.

The binary dependent variable "severity of herd response" was made by grouping none, mild and medium herd response in one level and strong and severe response in the other. When grouping of other dependent variable outcomes was done it is mentioned in the specific results section.

Differences in the mean of continuous variables related to the independent variables were investigated by using an ANOVA (linear model). Results of ANOVA were considered valid when primary assumptions of the ANOVA were met (equal variance among levels of independent variables, normality of residuals). Levene's test was used to detect unequal variances, with p values smaller than 0,2 indicating unequal variance. In case of unequal variance among groups, normality of residuals was not checked and a non-parametric test for difference in medians was used to investigate the relationship. Relations between continuous variables were investigated by calculating their correlation (Pearson). All analyses were conducted using SPSS 21.

3. Results

Overall, a total of 133 interactions between different bovine species and recreational visitors have been documented on video during the field research period of 1st of November 2013 till the end of February 2014. The interactions consisted of 55 observations of a walker, 49 of a walker with a dog and 29 observations of a jogger. All results are presented below by order of the secondary research questions.

3.1 What are the differences in response of bovine species (all breeds together) to three types of recreational visitors?

An overview of the percentages of a behavioural response for all herds tested with no distinction between the different types of interaction (walker, walker with a dog and jogger) is shown in figure 2. "Looking" (50%) is the most common response of a bovine herd when encountering a recreational visitor. Other responses like approaching and getting up from a lying position are rare.

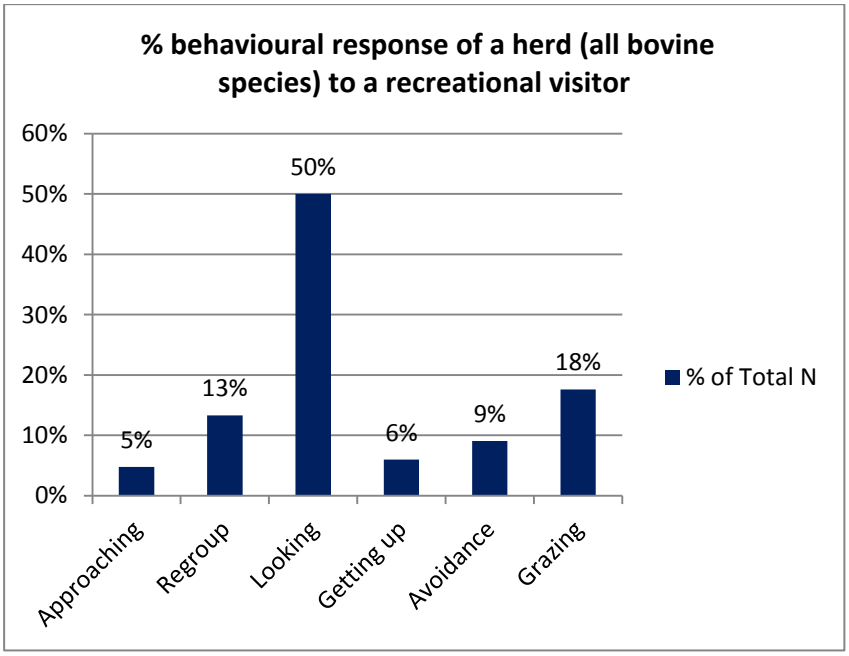

Figure 2. Total percentage of behavioural response of a herd when encountering a recreational visitor.

3.1.1 Does the *type of reaction* of a herd differ when encountering different types of recreational visitors?

To be able to test this question the behavioural data of all herds and all bovine species was combined. In figure 3 the percentage a behavioural response by a herd per type of interaction is shown. There was no significant difference between the mean percentages within a type of behavioural response to the different types of interactions simulated (walker, walker with a dog and a jogger). The outcome of type of interaction as a single model factor is shown in table 4. No significant difference between a walker, walker with a dog and a jogger in the type of behavioural response by a herd could be identified (all p-values are much larger than 0,05).

As stated above, approaching and getting up can be considered rare events. Rare events have 2 disadvantages, they might occur by chance and/or they cannot be tested due to quasi- separation. This means that levels of the independent variable do not have enough of the two possible outcomes and no comparison can be made. This strongly limits the use of these rare events for analysis and inference.

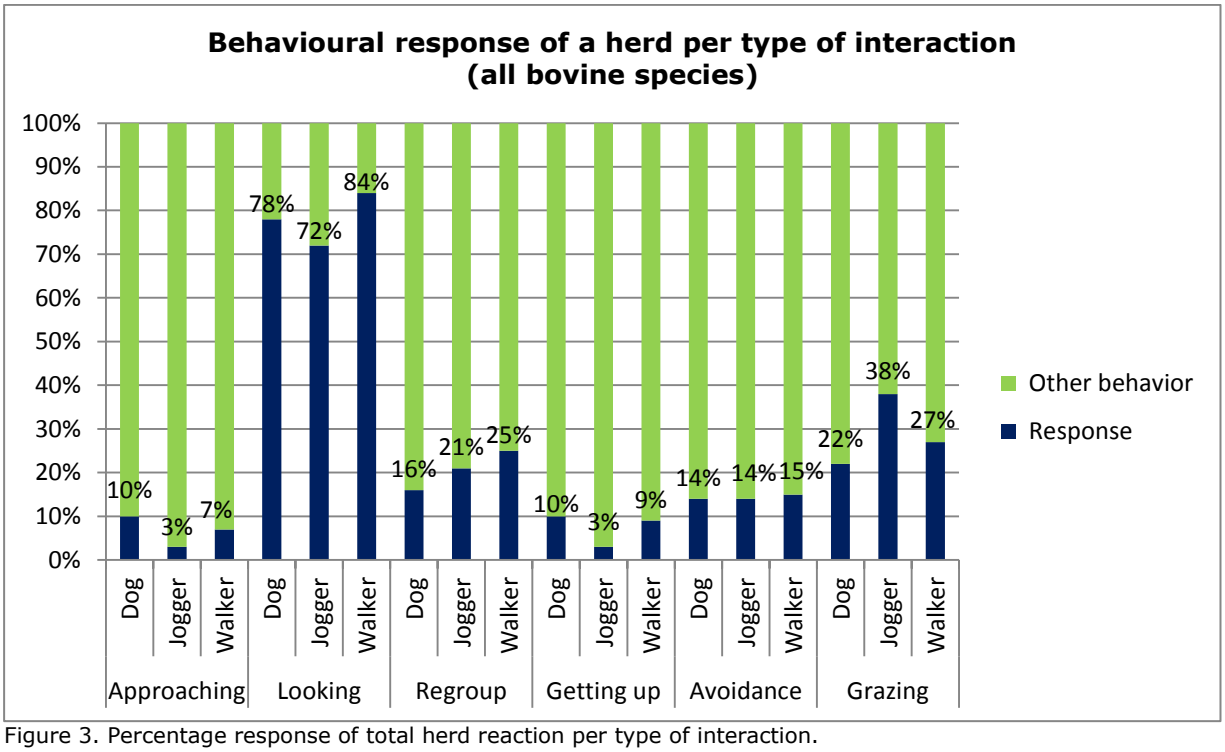

Figure 3. Percentage response of total herd reaction per type of interaction.

Table 4. Type of behavioural response of a herd to different types of interactions, overall p value and description of effect.

Direction total herd response: all herds with type of interaction as model factor		
Behavioural element:	P value*	significant effect
Approaching	0,570	None
Looking	0,518	None
Regroup	0,471	None
Getting up	0,583	None
Avoidance	0,996	None
Grazing	0,341	None

* Chi square p value of intercept-only model versus model with type of interaction as single model factor.

3.1.2 Does *severity of the reaction* of a herd differ when encountering different types of recreational visitors?

In order to increase test power all the strong and severe behavioural reactions were pooled together versus the none, mild and medium behavioural reactions test (see section 2.3 for definition). Figure 4 shows the percentage of the strong and severe herd responses for the different types of interactions versus the none, mild and medium responses. The results show no significant difference in the occurrence of strong-severe behavioural responses of a bovine herd between encountering a walker, walker with a dog or a jogger (single factor model p-value: 0,820).

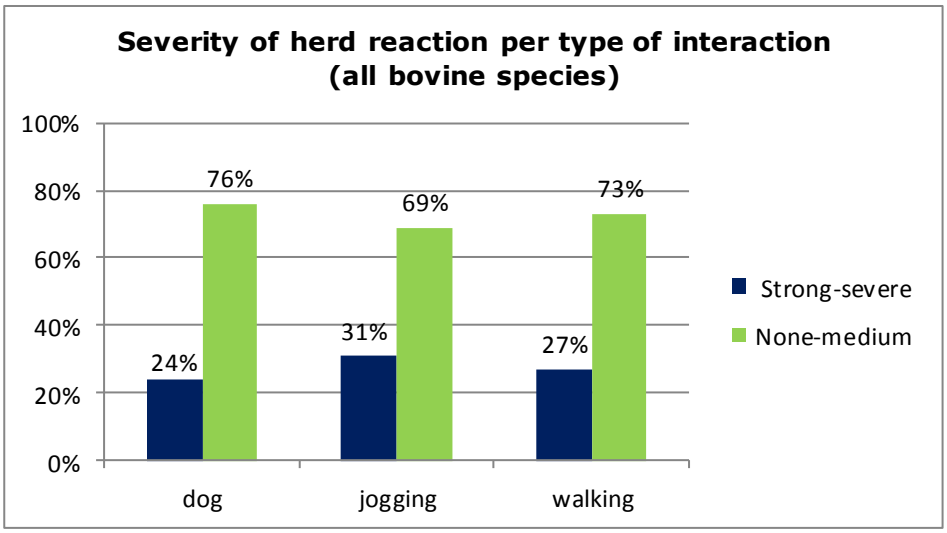

Figure 4. Percentage strong and severe response per type of interaction.

3.1.3 Is there a difference in *who reacts first: male, female or youngster* to different types of recreational visitors?

The percentage females in the dataset was far higher than males because a herd commonly consists of more female individuals. Females tend to react first when encountering a recreational visitor. Figure 5 shows the fraction of male and female responding to the different types of test. The overall p value for the association of type of test with gender of first reacting animal was 0,403, so no association existed in this data, males or females are not more prone to respond to a certain type of test.

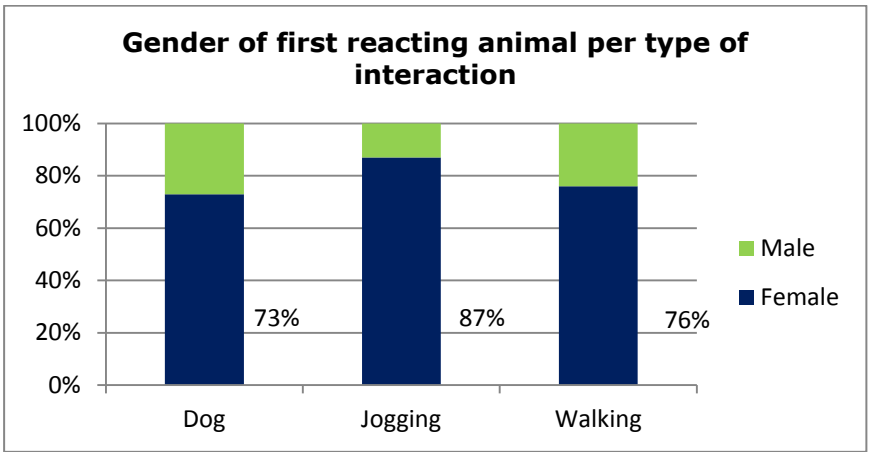

Figure 5. Percentage of male and female of first reacting animal per type of interaction.

When the chance of a male or youngster reacting first is based on the amount of males and youngsters present, it is possible to compare the expected and observed number of specific first reacting animals. Results of this comparison are shown in table 5. In the case of a walker with a dog, males tended to respond more often than expected (p value 0,0666). For the other types of test no difference was found. In the case of youngsters, (near) significant differences were found for all 3 types of tests. Youngsters showed less first responses than adults (table 5).

Table 5. Gender of first reacting animal per type of test, comparison of response fraction. N males herd and N youngster herd = total number of males and youngsters respectively in all herds together; N animals herd = total number of individuals in all herds together; N first response male and youngster = number of males and youngsters, respectively that responded first; N first responses = total number of individuals that responded first.

Gender first responding animal vs type of test					
type of test	N males herd	N animals herd	N first response: male	N first responses	p value*
walker	75 (17%)	440	12 (24%)	49	0,292
walker with dog	37 (13%)	275	11 (27%)	41	0,0666
jogger	28 (18%)	156	3 (13%)	24	0,5736
Sum	140 (16%)	871	26 (23%)	114	0,1359
Age of first responding animal vs type of test					
type of test	N youngster herd	N animals herd	N first response: youngster	N first responses	p value chisq
walker	171 (34%)	440	9 (18%)	49	0,0438
walker with dog	121 (44%)	275	9 (22%)	41	0,0705
jogger	59 (38%)	156	3 (13%)	24	0,099
Sum	351 (40%)	871	21 (18%)	114	0,0011

* Chi square test.

3.1.4 Is there a difference in the distance to the herd when the first reaction occurs (alert distance) when encountering different types of recreational visitors?

Figure 6 shows a boxplot of the distance (in meters) to the herd when the first behavioural reaction occurs. Few outliers are present and p value of the Levene test for equality of variance (p value: 0,901) indicates that variance of alert distance among the different interactions is equal. No pattern exists in the residuals. The p-value for difference in mean alert distance between the different types of interaction was 0,871, meaning there is no significant difference in alert distance between a walker, walker with a dog and a jogger. The explanative power of type of interaction for distance is very low. Expressed as an R square value, only 0,2% of the variation in alert distance was related to the type of test.

It is reasonable to think that alert distance is confounded by the size and type of the habitat, only larger habitats can have larger distances. There might be an operator effect too, in covered habitats for example the video cannot start until the operator has moved close enough to the cattle.

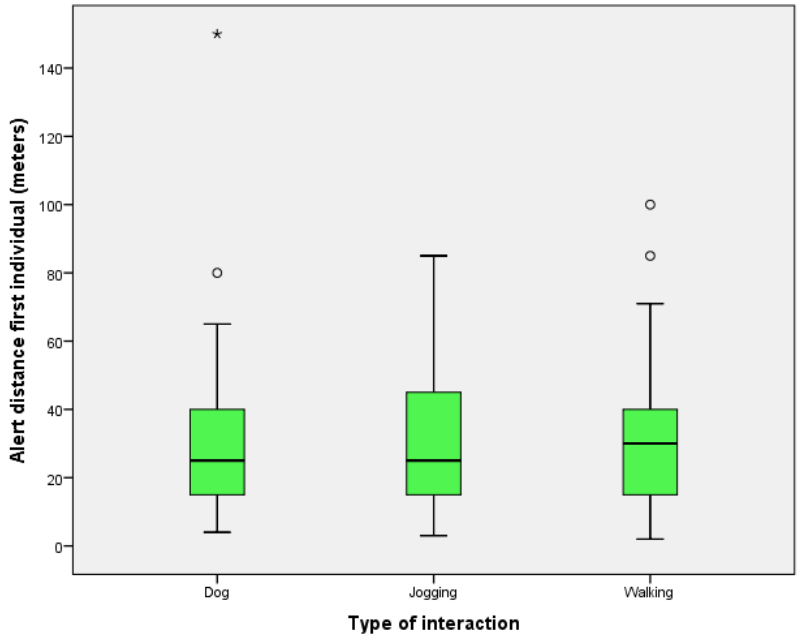

Figure 6. Boxplot of alert distance (meters) per type of interaction. Median values are represented by the black line in the box, bottom and top of box are 25 and 75 percentiles and error bars are the 95% confidence intervals. Outliers are shown as circles (1.5 times the interquartile range) or stars (3 times the interquartile range).

3.1.5 Is *reaction-time of first individual* of a herd different between types of recreational visitors?

The time (seconds) until the first individual of a herd responded to a type of recreational visitor is shown in a box-plot (figure 7). As can be seen in the plot, first individual response time contains a lot of extreme values. These extreme values caused the Levene test to be significant (p value 0,028) making an ANOVA test not suitable to investigate a possible difference in mean time between interaction types. So a test for difference in median was used, which returned a p value of 0,293, meaning that there is no significant difference in medians of the reaction-time between interactions with a walker, a walker with a dog and a jogger.

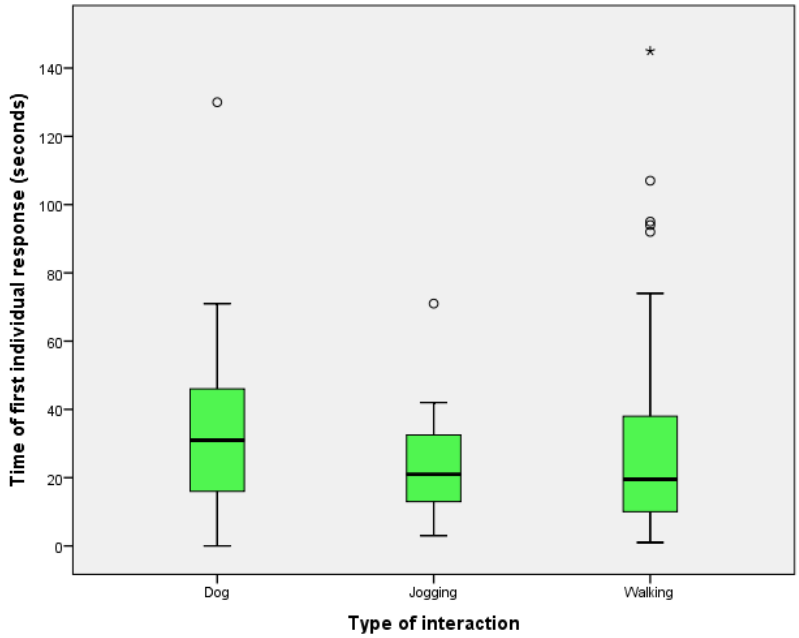

Figure 7. Boxplot of time (seconds) before first individual response occurred. Median values are represented by the black line in the box, bottom and top of box are 25 and 75 percentiles and error bars are the 95% confidence intervals. Outliers are shown as circles (1.5 times the interquartile range) or stars (3 times the interquartile range).

As was the case with distance, this variable is potentially confounded by habitat size, habitat cover and operator noise.

3.1.6 Is *speed of the reaction* different between different types of recreational visitors?

All behavioural reactions are categorized in three main speed groups; stationary, walking and running (for definition see section 2.3, table 2). Figure 8 shows the speed of the behavioural response to the different types of recreational visitors. The majority of the reacting individuals did not move and remained stationary. Jogging was strongly associated with a running response (p value 0,007, table 6), which is mirrored by a difference in stationary speed, jogging was associated with less stationary responses (table 6). A jogger caused more individual animals to react by moving than walkers of walker with a dog.

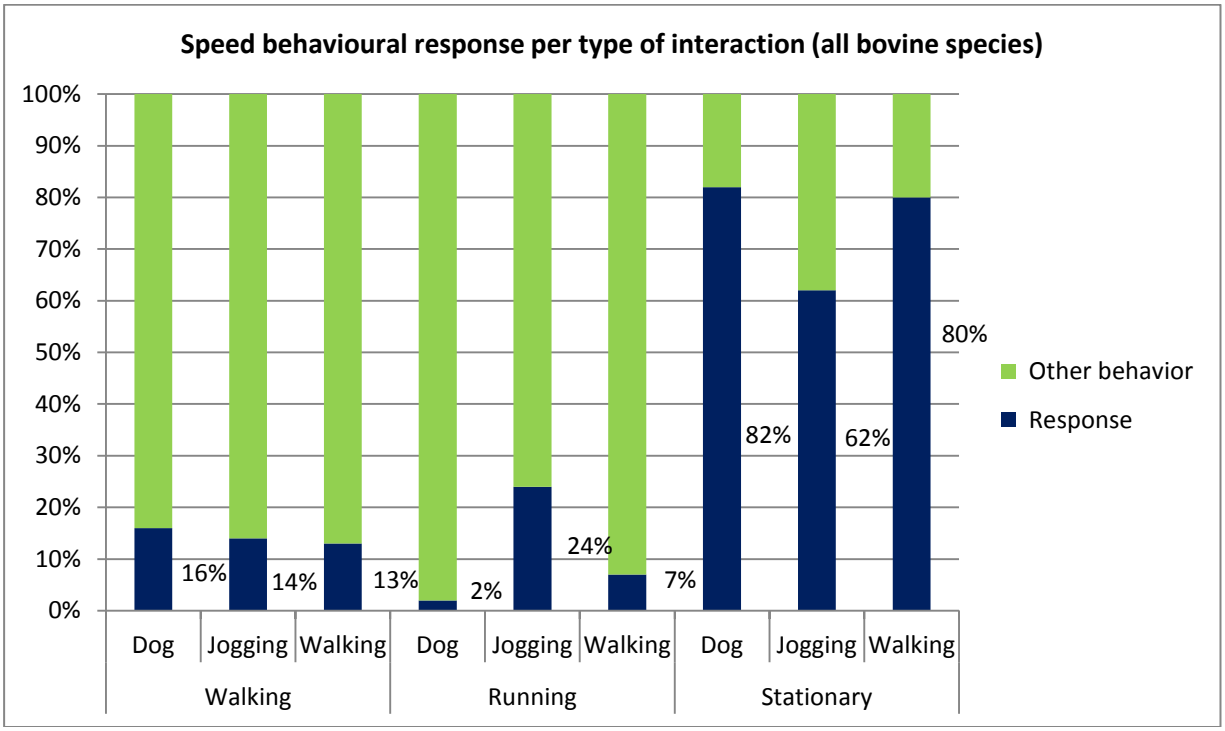

Figure 8. Percentage speed of individual behavioural response to different types of recreational visitors.

Table 6. Speed of behavioural response per type of interaction, overall factor p value, pairwise testing p value and description of effect.

Speed of behavioural response: all bovine species with type of interaction as model factor				
Behavioral element:	**Type of test**	**Factor p value [1]**	**Pairwise effect p ~= 0,05**	**Pairwise p value [2]**
Walking	Dog	0,884	None	Na
	Jogging			
	Walking			
Running	Dog	0,188	Jogging more response than dog	0,007
	Jogging		Jogging more response than walking	0,055
	Walking			
Stationary	Dog	0,122	Dog more response than jogging	0,064
	Jogging		Walking more response than jogging	0,096
	Walking			

[1] Chi square p value of intercept-only model versus model with behavioural element as single model factor
[2] Chi square p value of difference in means in pairwise test

3.1.7 Is *type of behavioural reaction* of the first individual, associated with the *severity* of the herd reaction?

Figure 9 shows the percentages of strong and severe herd responses (see table 3 for explanation of the categories) for the different behavioural reactions of the first individual to respond. The overall percentage of the occurrence of a strong-severe response is 39% in the data. Table 7 gives the comparison of the severity that followed different first individual reactions to the overall severity mean. There are some differences in severity of herd response; regroup and avoidance are strongly positively associated with a strong-severe response whereas looking, getting up and grazing have a strong negative association with strong-severe responses. This means that when the first behavioural reaction to a recreational visitor is regrouping or avoidance, the chance that a strong or severe herd reaction occurs is high.

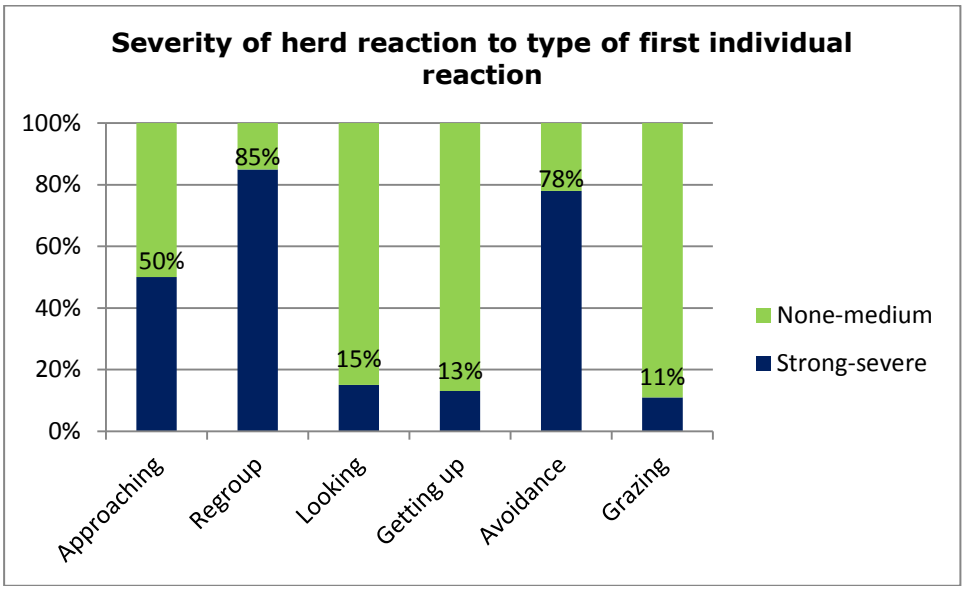

Figure 9. Percentage of herd reaction in relation to type first individual response.

Table 7. Results of herd severity deviation to mean testing of first individual reaction.

Type of first individual reaction: deviation contrast	Contrast estimate	Wald Chi-Square	df	Sig.
Level approaching vs. mean	0,10	0,219	1	0,64
Level regroup vs. mean	0,46	19,542	1	<0,001
Level looking vs. mean	-0,27	19,7	1	<0,001
Level getting up vs. mean	-0,29	7,282	1	0,007
Level avoidance vs. mean	0,36	8,341	1	0,004
Level grazing vs. mean	-0,31	9,424	1	0,002

3.2 Can we identify external factors that influence the behavioural reaction of bovine species to different types of recreational visitors?

In the results described above, there generally was no difference in the amount of specific behaviour in response to the different interaction types. In this section we describe the results of the other independent variables, breed, habitat, time of day, and gender of reacting animals.

3.2.1 Does *breed* influence the reaction of bovine species?

Breed: type of behavioural reaction

Figure 10 shows the type of behavioural reactions per breed. The elements approaching and avoidance could not be compared due to rarity and quasi-separation and are thus not displayed in figure 10. Significant differences existed between breeds for specific behavioural responses. Tauros displayed more regrouping behaviour than Wisent, Galloway and Scottish Highland cattle. Tauros looked more than Scottish Highland cattle and grazed less than the others. (table 8). A significant difference in the amount of grazing was found for the pairwise comparison of Wisent and Galloway (table 8).

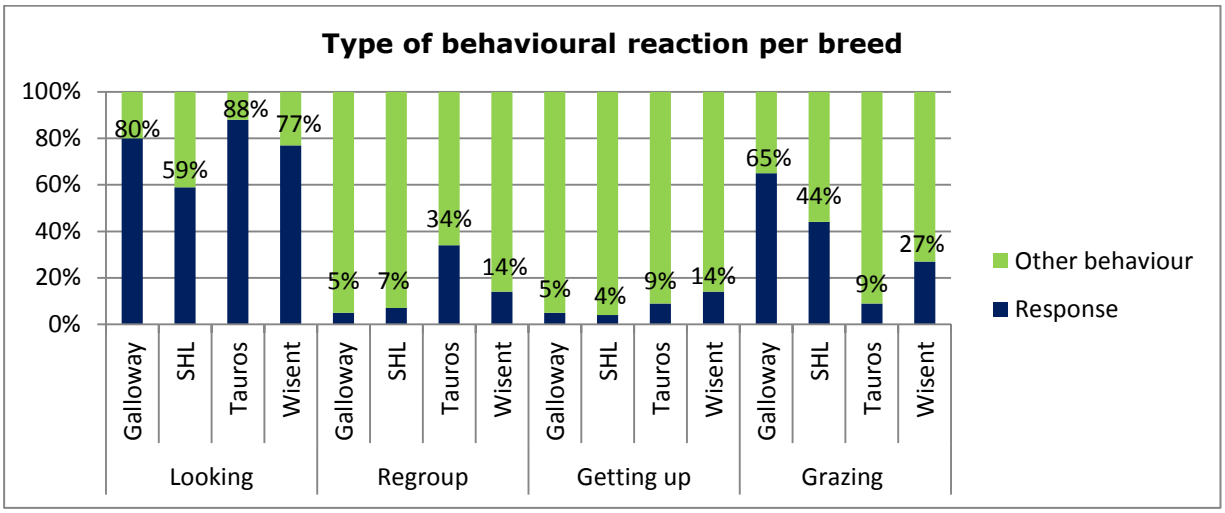

Figure 10. Percentage of type of herd reaction per breed, data labels indicate response. SHL: Scottish Highland cattle.

Table 8. Behavioural reaction of a herd per breed, overall factor p value, pairwise testing p value and description of effect.

behavioural reaction per breed				
Behavioural element:	**Breed**	**Factor p value [1]**	**Pairwise effect p ~< 0,05**	**Pairwise p value [2]**
Looking	Galloway	0,038	Tauros more looking than SHL	0,006
	SHL[3]			
	Tauros			
	Wisent			
Regroup	Galloway	0,01	Tauros more regrouping than Galloway	0,001
	SHL		Tauros more regrouping than SHL	<0,001
	Tauros		Tauros more regrouping than Wisent	0,028
	Wisent			
Getting up	Galloway	0,612	Na[4]	Na
	SHL			
	Tauros			
	Wisent			
Grazing	Galloway	<0,001	Tauros less grazing than Galloway	<0,001
	SHL		Tauros less grazing than SHL	0,001
	Tauros		Tauros less grazing than Wisent	0,078
	Wisent		Wisent less grazing than Galloway	0,008

[1] Chi square p value of intercept-only model versus model with behavioural element as single model factor.
[2] Chi square p value of difference in means in pairwise test.
[3] SHL: Scottish Highland cattle.
[4] Na: not applicable.

Breed: Speed of the behavioural reaction

The elements walking and running (12 observations) were pooled for this analysis. The percentages of the elements walking/running and stationary are displayed in figure 11. Though not a strong model factor (p value 0,284, table 9), there was a near-significant difference (p value 0,069) for the amount of walking/running and stationary reaction, with Wisent being more prone to walk or run than Galloway (table 9). There were no differences in the amount of walking as a behavioural reaction per breed.

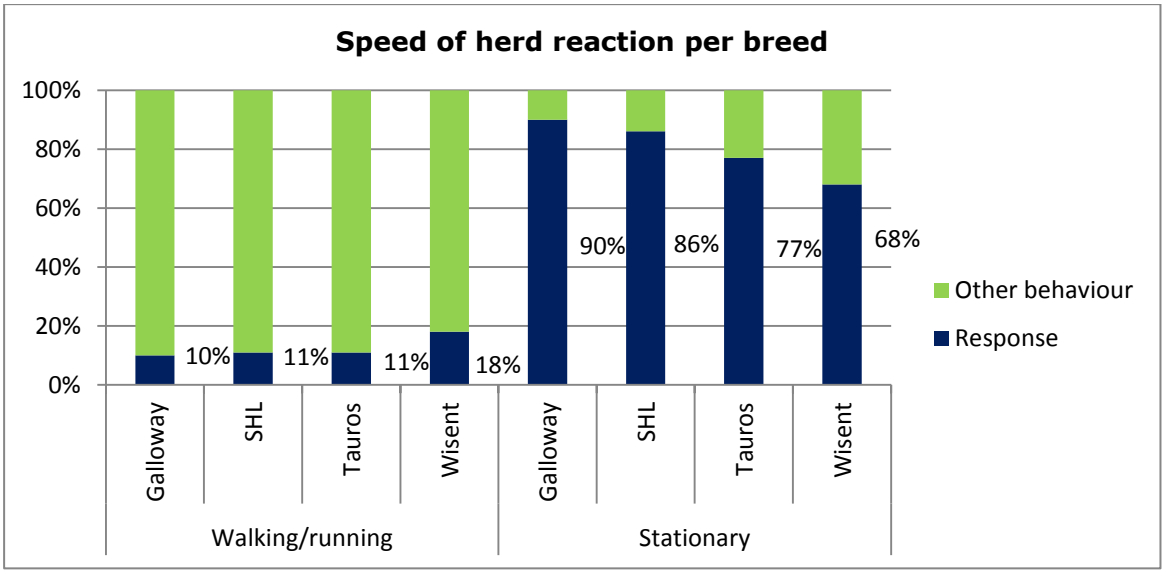

Figure 11. Speed of herd reaction per breed. SHL: Scottish Highland cattle.

Table 9. Speed of herd reaction per breed, overall factor p value, pairwise testing p value and description of effect.

Speed of herd reaction per breed				
Behavioral element:	**Type of test**	**Factor p value [1]**	**Pairwise effect p ~= 0,05**	**Pairwise p value [2]**
Walking/running	Galloway	0,284	Wisent more walking/running than Galloway	0,069
	SHL[3]			
	Tauros			
	Wisent			

[1] Chi square p value of intercept-only model versus model with behavioural element as single model factor.
[2] Chi square p value of difference in means in pairwise test.
[3] SHL: Scottish Highland cattle.

Breed: Severity of herd reaction

A strong significant difference was found between breeds for the severity of the herd reaction (figure 12, table 10). Both Tauros and Wisent gave more strong or severe reactions than Galloway and Scottish Highland cattle. Considering the results of pairwise testing (table 10), Tauros and Wisent are not different form each other as are Galloway and Scottish Highland cattle .

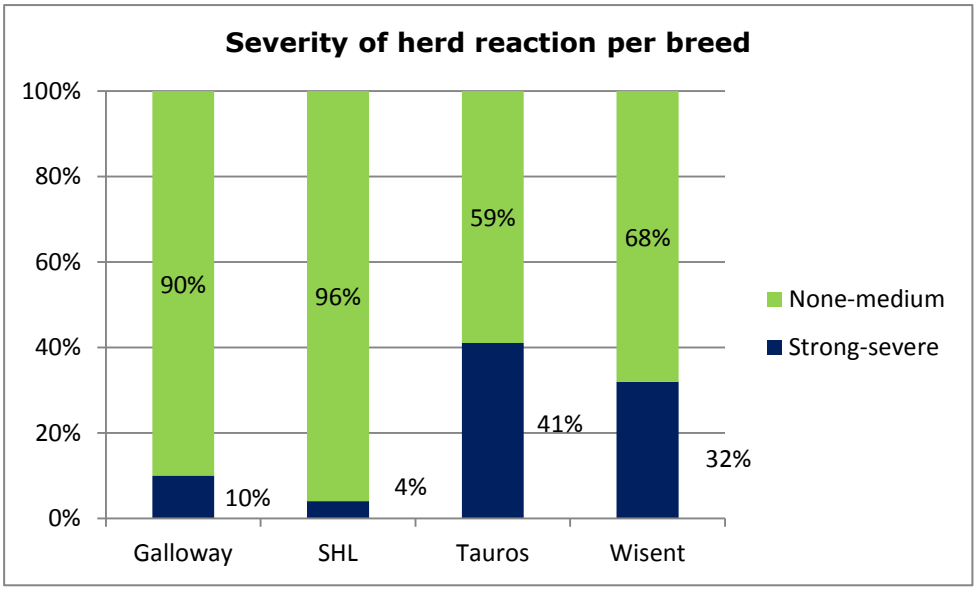

Figure 12. Percentage of strong-severe herd reactions per breed. SHL: Scottish Highland cattle.

Table 10. Severity of herd reaction per breed, overall factor p value, pairwise testing p value and description of effect.

Severity of herd response per breed		
Factor p value [1]	**Pairwise effect p ~< 0,05**	**Pairwise p value [2]**
0,008	Galloway less strong-severe response than Tauros	0,001
	SHL[3] less strong-severe response than Tauros	<0,001
	Galloway less strong-severe response than wisent	0,069
	SHL less strong-severe response than wisent	0,008

[1] Chi square p value of intercept-only model versus model with behavioural element as single model factor.
[2] Chi square p value of difference in means in pairwise test.
[3] SHL: Scottish Highland cattle.

Breed: Alert distance

The alert distance of the first individual to respond (meters) for the different breeds is presented in a boxplot (figure 13). A relatively large number of extreme values existed and the Levene p value for equality of variance (0,068) indicated that comparisons had to be conducted by using a non-parametric method. From the plot it can be seen that Tauros and Wisent have a greater alert distance than Galloway and Scottish Highland cattle. Overall, the p value of the independent samples Median test (p value < 0,0001) indicate a large difference in median values between the breeds. Pairwise test grouped together Galloway and SHL versus Tauros and Wisent, with Wisent and Tauros differing from each other. So these results support the conclusion that alert distance is smaller for Galloway and SHL than for the Tauros and Wisent (table 11). The effect of breed on alert distance might be confounded by the fact that certain breeds are more prone to be in larger areas, leading to larger possible reaction distances. Alert distance also depends on habitat cover, regardless of habitat size.

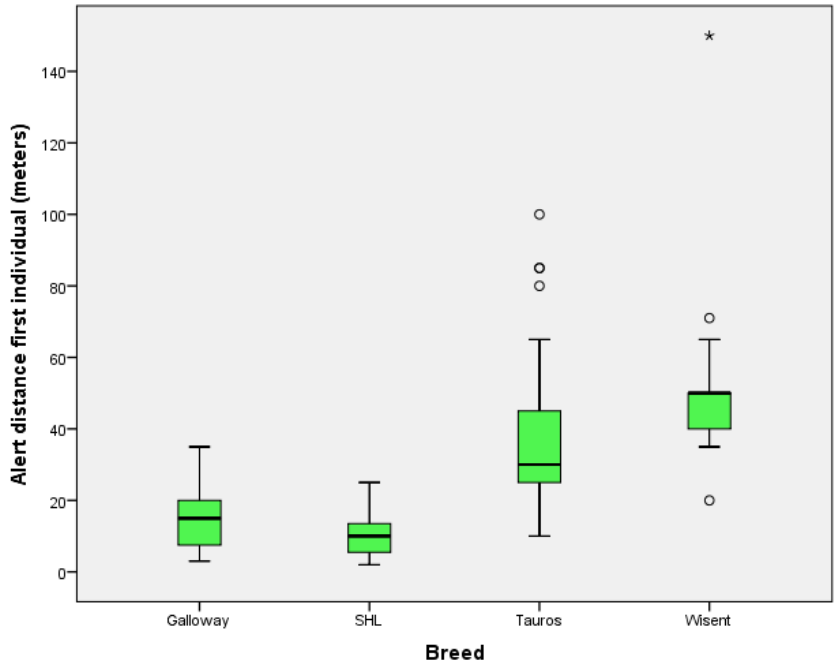

Figure 13. Boxplot of alert distance (meters) per breed. Median values are represented by the black line in the box, bottom and top of box are 25 and 75 percentiles and error bars are the 95% confidence intervals. Outliers are shown as circles (1.5 times the interquartile range) or stars (3 times the interquartile range).

Table 11. Independent-samples Median test on difference in alert distance per breed pair

Pairwise test for difference in median	
Pair	Pairwise test result value[1]
SHL[2]-Galloway	0,112
SHL-Tauros	<0,0001
SHL-Wisent	<0,0001
Galloway-Tauros	0,004
Galloway-Wisent	<0,0001
Tauros-Wisent	<0,0001

[1] Chi square p value.
[2] SHL: Scottish Highland cattle.

Breed: Time of the first individual response

Figure 14 shows the boxplot of the first individual response time per breed. Confidence intervals largely overlap so no significant difference was expected. The Levene test for equality of variance returned a p value of 0,063 so ANOVA could not be used to test for difference in mean response time. P value of overall test for difference in median time was 0,254, meaning there was no difference in median value of response times between breeds.

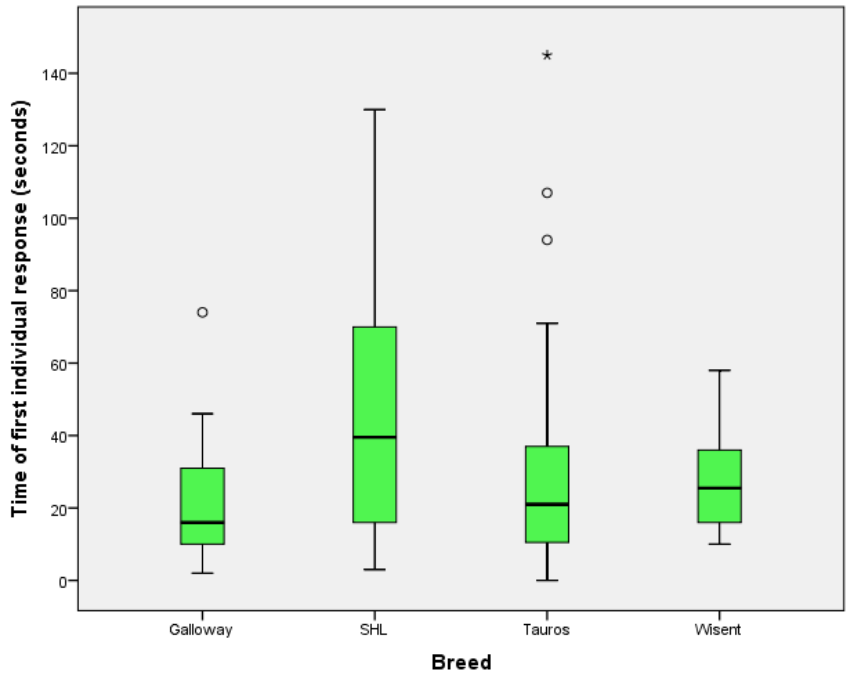

Figure 14. Boxplot of time (seconds) of first individual response per breed. Median values are represented by the black line in the box, bottom and top of box are 25 and 75 percentiles and error bars are the 95% confidence intervals. Outliers are shown as circles (1.5 times the interquartile range) or stars (3 times the interquartile range).

3.2.2 Does *habitat* influence the reaction of bovine species?

The factor habitat can be divided into two separate elements: cover and size. The element cover has been categorised using three levels; open (no trees or shrubs), half-open (some trees) and covered (forest). Habitat of the herds have different sizes, ranging from 13,2 Ha (hectare) to 400 hectare.

Unfortunately, no testing of the relation between habitat size and type of behavioural reaction (grazing, avoidance etc.) or the relation between habitat size and severity could be conducted. The types of behavioural reactions were too rare to have a reliable relation with the different habitat sizes and resulted in quasi-separation. Alert distance and time of first individual response could be analysed.

Habitat cover: severity of herd response

Habitat type proved to be a significant factor in a model for severity of response (figure 15) with all three habitats differing from each other at p values <0,05. A covered habitat was strongly associated with most strong-severe herd reactions. Unfortunately, this variable is confounded because no interactions have been documented for Galloway and Scottish Highland cattle in covered habitat making covered habitat rare (N=6).

When the analysis is repeated without Galloway and Scottish Highland cattle, with Tauros and wisent only, the resulting associations distinguished covered from half-open and open (p values 0,001 and 0,013). The amount of strong or severe herd reactions was not different between half open and open habitat (p value 0,156).

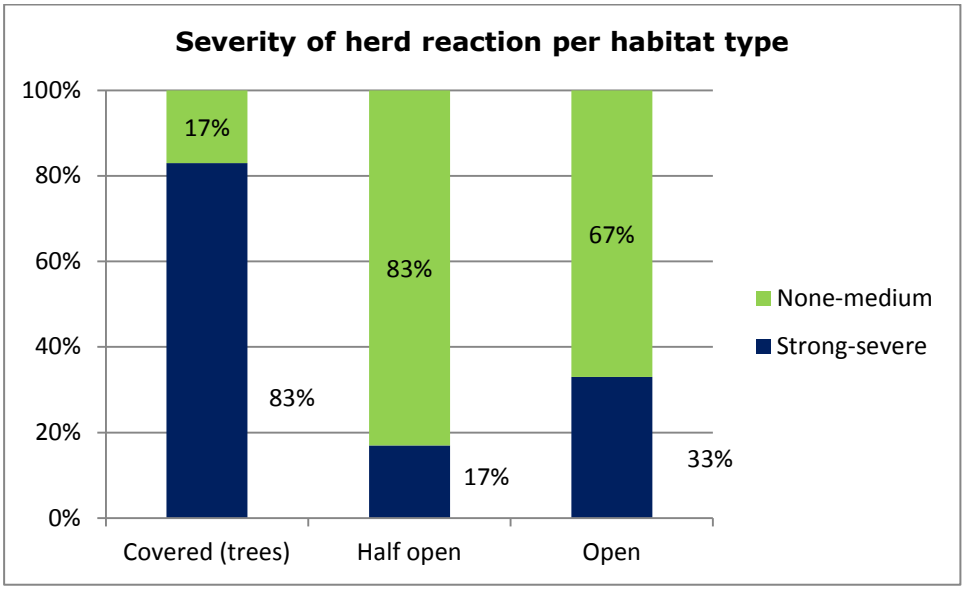

Figure 15. Percentage of strong-severe herd reactions per habitat type.

Habitat cover: Alert distance

Figure 16 shows the boxplot of the alert distance of the first individual to respond per habitat type. Confidence intervals largely overlap and the ANOVA used to detect effects of habitat type revealed no significant differences (p value 0,289).

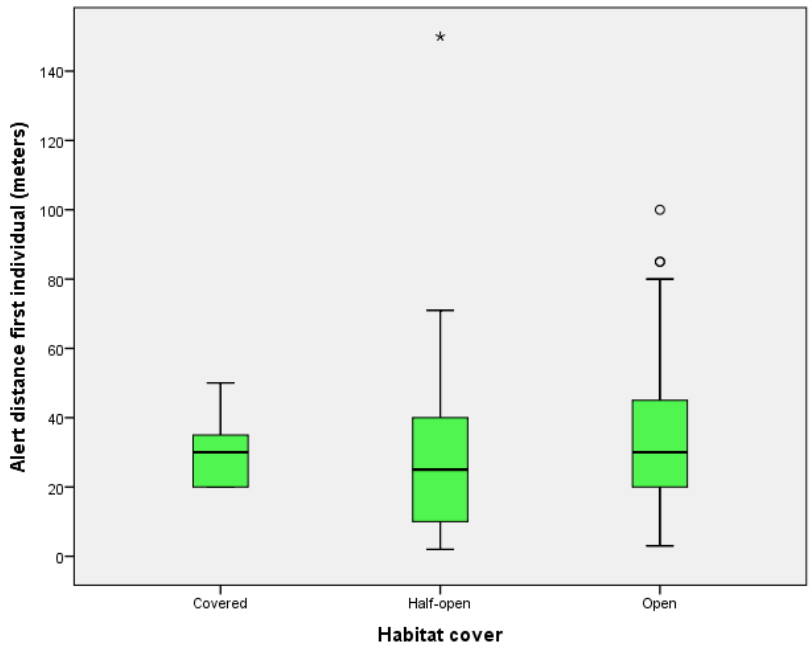

Figure 16. Boxplot of alert distance per habitat cover type. Median values are represented by the black line in the box, bottom and top of box are 25 and 75 percentiles and error bars are the 95% confidence intervals. Outliers are shown as circles (1.5 times the interquartile range) or stars (3 times the interquartile range).

Habitat cover: time of first individual response

Figure 17 shows the boxplot of the time of the first individual response per habitat. The Levene test for equality of variance returned a p value of 0,300 so ANOVA was used to test for difference in mean response time (p= 0,867). There was no difference in mean time of first individual response. As was the case with severity and distance of first response, the variable is confounded by breed and suffers from rarity of its levels.

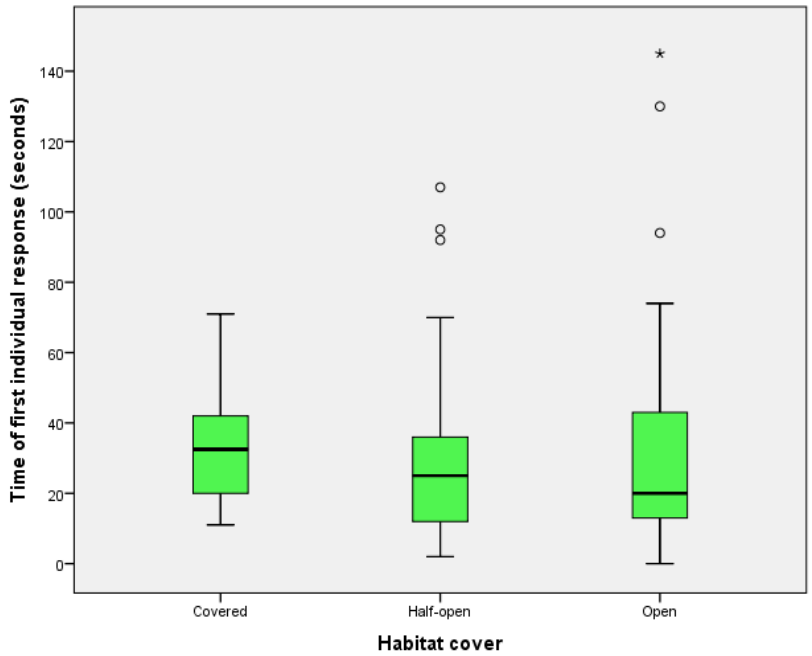

Figure 17. Boxplot of time of first individual response per habitat cover type. Median values are represented by the black line in the box, bottom and top of box are 25 and 75 percentiles and error bars are the 95% confidence intervals. Outliers are shown as circles (1.5 times the interquartile range) or stars (3 times the interquartile range).

Habitat size: Alert distance

Figure 18 shows the boxplot of the alert distance per habitat size. The variable habitat size is categorical in nature because the data are small and the amount of habitats is limited. This affects the statistical possibilities in the sense that response distance gets to be fragmented over the levels of habitat size, observations become rare and the role of chance increases. This fragmentation effect leads to a very small p value of the Levene test, so the variance of mean distance among habitat sizes cannot be considered equal. The p value of the test for difference in median was 0,09, meaning no difference was found between medians.

Apart from the test results indicating that there is no difference between size of habitat in alert distance, the relation is not uniform/linear if the mean is considered. Figure 19 shows the mean value of distance for the habitat sizes. The relation has an "oscillation" in it, probably caused by outliers and chance, preventing a useful interpretation of the effect of habitat size.

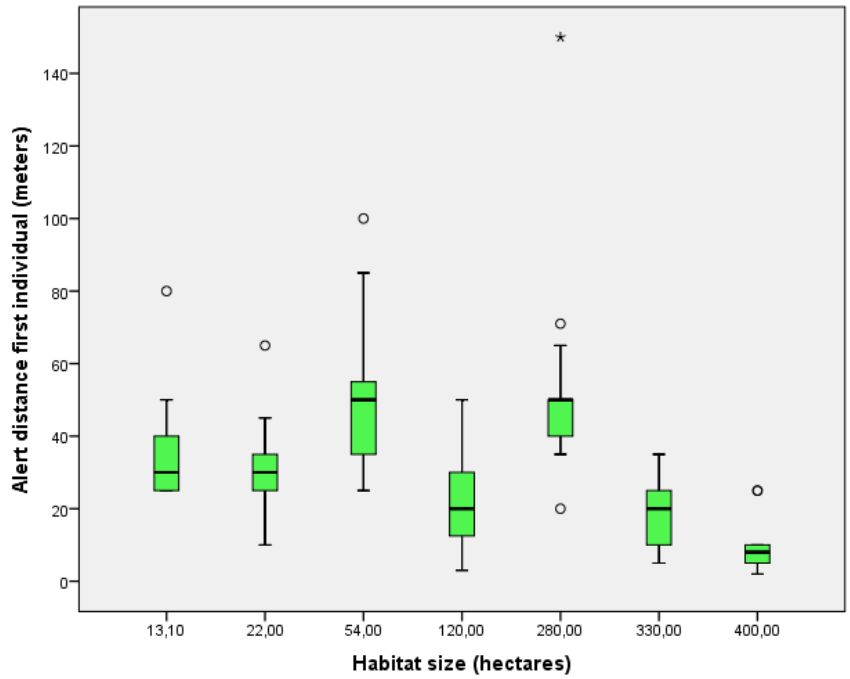

Figure 18. Boxplot of alert distance per habitat size. Median values are represented by the black line in the box, bottom and top of box are 25 and 75 percentiles and error bars are the 95% confidence intervals. Outliers are shown as circles (1.5 times the interquartile range) or stars (3 times the interquartile range).

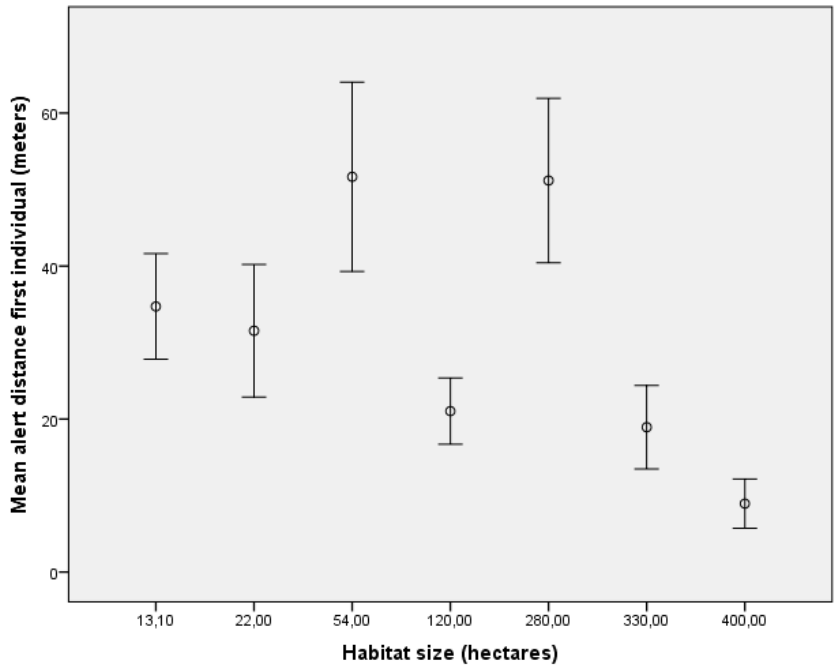

Figure 19. Plot of mean of alert distance per habitat size. Error bars represent the 95% confidence interval of the mean.

Habitat size: time of first individual response

Figure 20 shows the boxplot of time of first individual response per habitat size. Mean time per habitat type could not be compared by ANOVA as the Levene test was strongly significant (p value 0,001). The test for difference in medians returned a p value of 0,09. This is near significant but not enough to make automated pair wise testing possible. Figure 20 contains a slight trend that larger habitat sizes have a larger median first response time. But the spread of the observations, shown by the confidence intervals, and the notion that effect of habitat size is confounded by at least breed, do not allow causal inference with this independent variable.

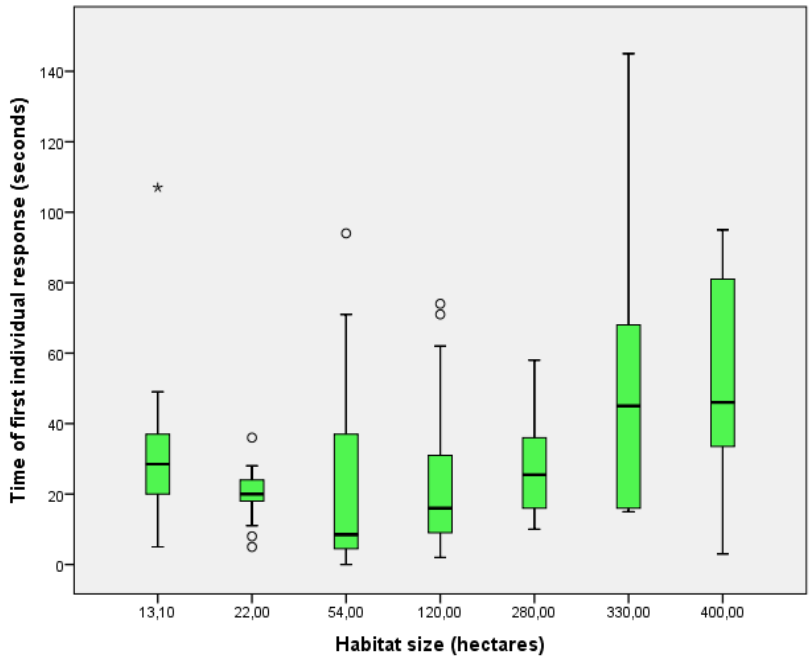

Figure 20. Boxplot of time of first individual response per habitat size. Median values are represented by the black line in the box, bottom and top of box are 25 and 75 percentiles and error bars are the 95% confidence intervals. Outliers are shown as circles (1.5 times the interquartile range) or stars (3 times the interquartile range).

3.2.3 Does *time of day* influence the reaction of bovine species?

Ideally, time of day of test is a continuous variable. But for this data, the number of time points is limited and time points tend to be clustered around certain values. So time was transformed to a categorical variable, distinguishing three levels (table12). The influence of time of day on the speed of herd reaction, severity of reaction, alert distance and time of first individual to respond are analysed.

Table12. Time categories and number of observations.

Time category	N observations
10:00-12:00	29
12:00-14:00	56
14:00-16:30	49
Total	134

Time of day and severity of herd response

Figure 21 shows the percentage of strong-severe herd responses for the different time categories (p value 0,022, table 13). The earlier time categories had significantly less strong-severe herd reactions than the time category 14:00 -16:30. The results are confounded by breed, because Wisent observations were never in an early time category. But when the Wisent observations are excluded, the differences between time categories stay significant. This means the chance of a strong or severe herd reaction occurring to a recreational visitor increases later in the day.

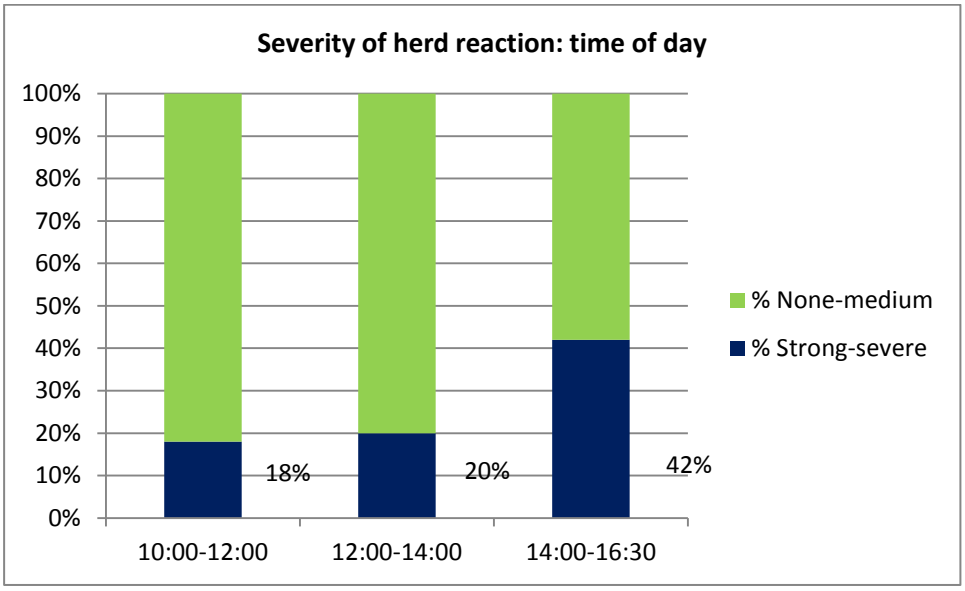

Figure 21. Percentage of strong-severe herd reactions per time of day category.

Table 13. Severity of herd reaction time of day, overall factor p value, pairwise testing p value and description of effect.

Severity of herd response: time of day		
Factor p value [1]	**Pairwise effect p ~< 0,05**	**Pairwise p value [2]**
0,022	10:00-12:00 less strong-severe response than 14:00-16:30	0,019
	12:00-14:00 less strong-severe response than 14:00-16:30	0,013

[1] Chi square p value of intercept-only model versus model with behavioural element as single model factor.
[2] Chi square p value of difference in means in pairwise test.

Time of day and speed of first individual response

No association of speed of first individual response with time of day was found. Overall model factor p values for the elements walking (0,780), running (0,330) and stationary (0,232) were far from the significance threshold.

Time of day and alert distance

Levene's test for equality of means indicated that ANOVA could be used to compare different mean distances (Levene p value: 0,334). ANOVA found no association between time of day and alert distance (p value: 0,667). Variation in alert distance explained by the model factor time of day was less than 1% (R square of 0,008). Characteristics of alert distance per time category are displayed in figure 22.

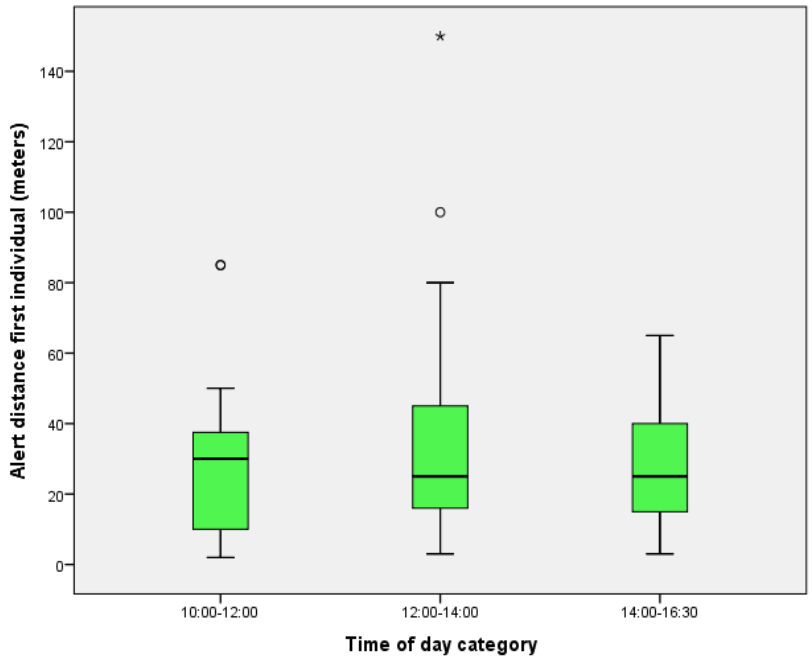

Figure 22. Boxplot of alert distance per time of day category. Median values are represented by the black line in the box, bottom and top of box are 25 and 75 percentiles and error bars are the 95% confidence intervals. Outliers are shown as circles (1.5 times the interquartile range) or stars (3 times the interquartile range).

Time of day and time of first individual response

Figure 23 shows the boxplot of time of first individual response per time of day category. For the comparison of mean time of individual response among time categories the Levene test was significant (p value 0,018), so the test for difference in median was used. This test gave an overall p value of 0,014. Pairwise testing showed a significant difference in median time of first individual response between 12:00-14:00 and 14:00-30. Later in the day, time of first individual response was shorter than during mid-day.

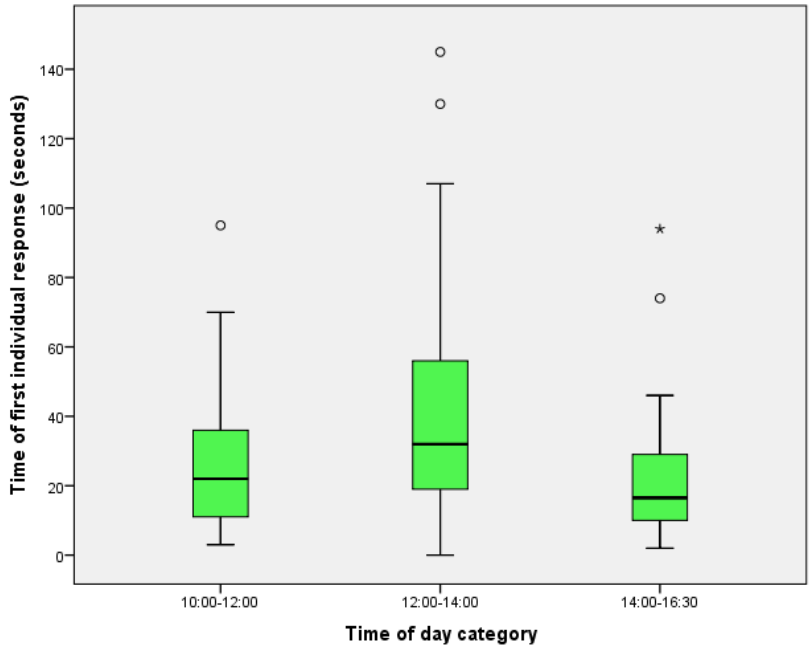

Figure 23. Boxplot of time of first individual response per time of day category. Median values are represented by the black line in the box, bottom and top of box are 25 and 75 percentiles and error bars are the 95% confidence intervals. Outliers are shown as circles (1.5 times the interquartile range) or stars (3 times the interquartile range).

3.2.4 Does *herd size* influence the reaction of bovine species?

Behavioural reactions of a herd might be dependent on the herd size. Figure 24 shows herd size and frequency in the available data.

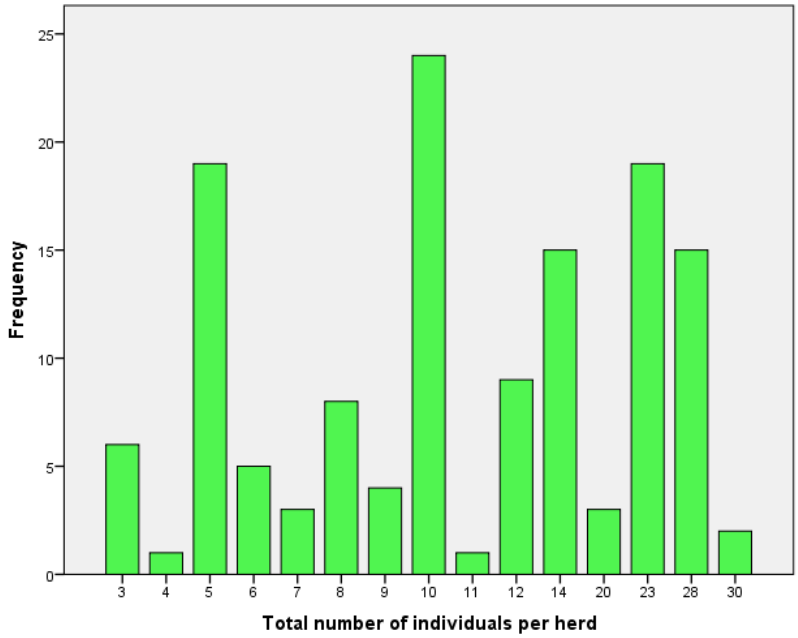

Figure 24. Histogram of herd size.

Herd size and severity of herd response.

Herd size was used as a continuous independent variable in a model having the fraction of strong-severe responses as the dependent. Overall model factor p value of herd size was 0,549, indicating that herd size has no association with the severity of a herd reaction. This fits with the estimated effect size of the continuous variable, -0,014. Which means that for every unit increase in herd size, the mean fraction of strong-severe herd responses goes down with 1,4 %. A minimal and non-significant effect for an independent that ranges from 3 to 30 (figure 24).

Herd size and alert distance

The relation between herd size and alert distance was investigated by calculating the correlation between the two continuous variables (Table 1). As was the case with severity, a very small and non-significant effect was seen. Alert distance decreased slightly with an increase in herd size.

Table 14. Correlation between herd size and alert distance.

Total individuals herd vs. alert distance	Pearson Correlation	-0,029
	Sig. (2-tailed)	0,743
	N	134

Herd size and time of first individual response

The correlation between herd size and time of first individual response was not significant. A minimal positive effect existed, response time increased slightly with increased herd size (table 15).

Table 15. Correlation between herd size and time of first individual response.

Total individuals herd vs. time first individual response	Pearson Correlation	0,036
	Sig. (2-tailed)	0,713
	N	134

3.3 What is the relative importance of different factors influencing bovine behaviour?

In the previous analysis independent variables of cattle behaviour as single model factors were used. This lead to the identification of dependent and independent variables that influence the behavioural reactions of bovine species. In the current analysis the strongest factors were used to construct multifactorial models to identify the relative importance of the different factors. By comparing the magnitudes of their estimates and model fit of possible models, the main drivers behind cattle behaviour may be identified and quantified.

Not all dependent variables proved to be suitable for this test. For testing the variable "type of behavioural reaction" the number of observational data was too limited (some responses are rare events) in combination with the number of levels of the dependent. Rare events lead to quasi-separation, meaning not all response outcomes were present for all levels of independents. Also rare events suffer from coincidence, results that are not necessarily related to the experimental set up. The continuous dependents alert distance and time were generally noisy (many outliers), with noise obscuring the true relation between dependent and independent.

The best dependent variable is severity of herd response. Subsequently, this was used as dependent in a multifactorial model. The strongest independent factors were breed, time of day, habitat type and to a much lesser degree type of test. Table 16 gives an overview of the numerical characteristics of the data used for the multifactorial model. The presence of factors is nicely balanced, apart from type of habitat that for the level "covered" only has 6 observations. Note that for 2 observations not all data are available, so the total number of observations decreased to 132.

Table 16. Overview of available data for multifactorial model.

Categorical Variable Information			**N**	**Percent**
Dependent Variable	Strong- severe response	no, mild or medium reaction	96	72,70%
		strong or severe reaction	36	27,30%
		Total	132	100,00%
Factor	Breed of herd	Galloway	20	15,20%
		SHL[1]	27	20,50%
		Tauros	64	48,50%
		Wisent	21	15,90%
		Total	132	100,00%
	Type of interaction	Dog	48	36,40%
		Jogging	29	22,00%
		Walking	55	41,70%
		Total	132	100,00%
	Type of habitat herd	Covered (trees)	6	4,50%
		Half open	65	49,20%
		Open	61	46,20%
		Total	132	100,00%
	Timecat	10:00-12:00	28	21,20%
		12:00-14:00	56	42,40%
		14:00-16:30	48	36,40%
		Total	132	100,00%

[1] SHL: Scottish Highland cattle.

The linear model had the general shape of:

Severity = intercept+ Breed + Type of test + Type of habitat + Time category

The results of the overall strength of model factors (versus a null model) is shown in table 17. Breed (p value 0,002) and time of day (p value 0,003) have a similar significant effect and are the strongest drivers of severity of a herd reaction, type of habitat is close to significance (p value 0,079) and type of interaction has no effect (p value 0,577). The data are too small to investigate an interaction between breed and time, apart from time being confounded by breed (Wisent never early). We can conclude only that breed and the time of the day are relatively more important factors for the severity of the herd reaction than habitat type and type of recreationist are.

Table 17. Output multifactorial model.

Tests of Model Effects			
Source	Type III Wald Chi-Square	df	Sig.
(Intercept)	3,827	1	0,05
Breed	14,578	3	0,002
Type of interaction	1,099	2	0,577
Type of habitat	5,079	2	0,079
Time category	11,477	2	0,003

3.4 Are there differences in response between Tauros herds to three types of recreational visitors; a walker, walker with a dog and a jogger?

From the observational data it seems that there are differences between Tauros herds in their reaction to recreational visitors. Table 18 shows the number of observations for the different Tauros herds.

Table 18. Behavioural observations Tauros herds.

Categorical Variable Information			N	Percent
Dependent Variable	Strong-severe	no, mild or medium reaction	38	59,40%
		strong or severe reaction	26	40,60%
		Total	64	100,00%
Factor	location of herd	Grauss	18	28,10%
		Keent	6	9,40%
		Loozerheide	12	18,80%
		Siendonck west	13	20,30%
		Tungelrooyse beek	15	23,40%
		Total	64	100,00%

Because the behavioural observations of the Tauros encompasses only a small (N=64) subset of the data, severity of herd response is the only variable that can be used as dependent. Figure 25 shows the percentage of strong-severe reactions per Tauros herd. Herds are compared to the overall mean response (deviation contrast) which is 37% strong-severe response for Tauros in table 19.

The Tauros herds are not uniform in the percentage of strong-severe reactions. De Grauss and Keent have significantly lower strong-severe responses, whereas the Loozerheide and Tungelrooyse Beek showed significant higher percentages of strong and severe reactions.

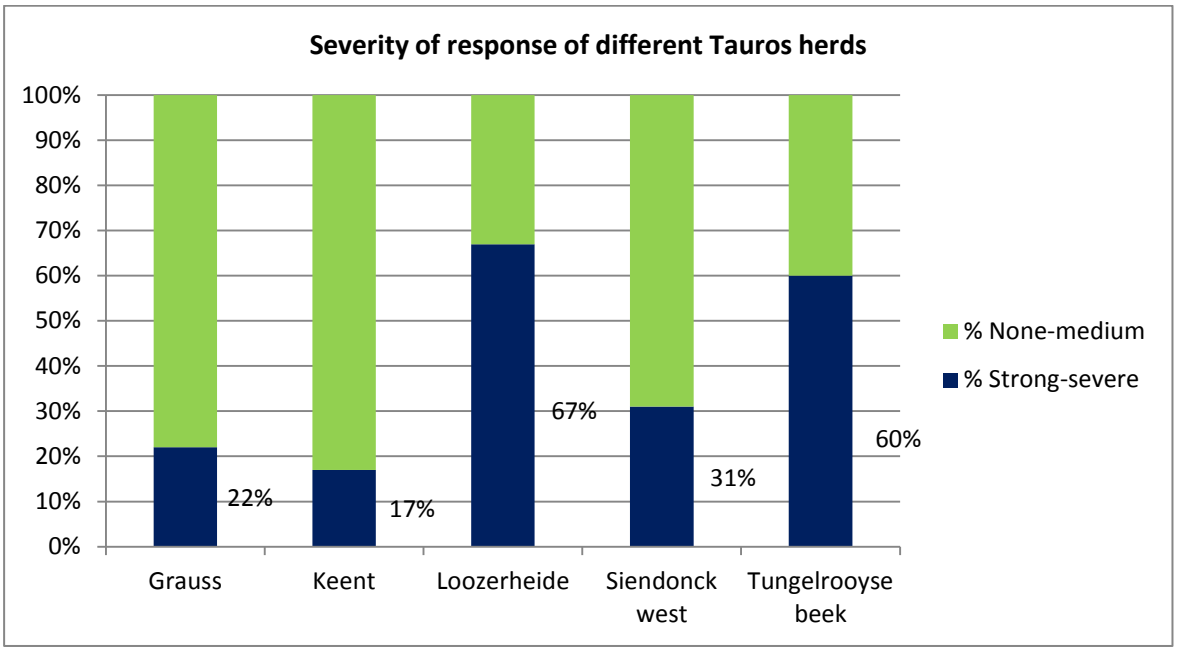

Figure 24. Percentage of strong-severe herd reactions for the different Tauros herds.

Table 19. Deviation to mean strong-severe of separate Tauros herds.

Test Results of individual Tauros herds					
Location of herd Deviation Contrast	Contrast Estimate	Std. Error	Wald Chi-Square	df	Sig.
Level Grauss vs. Mean	-0,17	0,095	3,189	1	0,074
Level Keent vs. Mean	-0,23	0,131	2,963	1	0,085
Level Loozerheide vs. Mean	0,27	0,12	5,194	1	0,023
Level Siendonck west vs. Mean	-0,08	0,115	0,548	1	0,459
Level Tungelrooyse beek vs. Mean	0,21	0,114	3,321	1	0,068

4. Discussion

The results show that the most common and initial reaction to a recreational visitor is to look up at the novelty in their environment. The second most common behaviour is to regroup with other herd members. Situations in which the recreational visitor was approached by cattle only occurred in 5% of the simulated interactions. Youngsters (age 1 to 2 years) and calves (age 0 to 1 year) had the strongest tendency to investigate the recreational visitor. This is in line with the findings of Herskin et al. (2004), that curiosity to a novel stimulus is the main reason for approaching behaviour. During the entire field testing period no direct signs of aggression towards a recreational visitor were displayed. Nevertheless, an approaching cow can be perceived as threatening or aggressive by the public due to the size of the animal and lack of knowledge on how to interpret cattle behaviour.

4.1 Differences in reaction of bovine species to three types of recreational visitors.

No differences in behavioural reaction to different types of recreational visitors were found. In the study population, the different herds did not react differently to a walker compared to a walker with a dog or a jogger. Overall, the gender of the individual that reacts first to a recreational visitor is female. This can probably be attributed to the fact that herds are almost always made up of mainly females. The alert distance and severity of the reaction were not statistically different for the three types of recreational visitors tested. This coincides with Taylor and Knight (2003) who found no or minimal differences in alert distance and distance for exposure to two types of recreation (hiking and biking) for three ungulate species (American bison, pronghorn antelope and mule deer). On the contrary Stankowich 2008) demonstrated a strong effect of the type of disturbance on flight behaviour of ungulates, where humans on foot were far more evocative than terrestrial vehicles, aircraft or anthropogenic noise. Furthermore, humans had more or equally evocative effects on ungulates as had canids (Stankowich 2008). In our study, behavioural reactions when facing a dog were not different from the reactions to other visitor types. It is generally assumed that cattle, being prey animals, perceive dogs as their natural predator the wolf (Kluever et al. 2009). The dog in our experimental set up was always on its own and this might resemble the effect of a single wolf. A single wolf poses no real threat to the much larger bovines. It should be kept in mind that our results are only based on the presence of one dog and moreover a dog that did not bark or growl at the bovine species nor displayed any aggressive behaviour. The effects of multiple dogs present or dogs growling and barking on behavioural reactions is still unknown.

Nearly all studies reviewed by Stankowich (2008) found that rapid or directly approaching humans are more evocative than slow or indirectly approaching humans. This coincides with our result that joggers provoked significantly more running responses. When the approaching visitor appears more threatening (faster and more direct), animals will flee at greater distances. Also the placement of the recreational visitor relative to the herd may influence the behavioural response. Taylor and Knight (2003) found that animals responded most to recreational visitors above them and least to visitors below them.

It might also be argued that a herd reaction is linked to the type of response of the first individual to react to the presence of a recreational visitor. Our results show that when the response of first individual is to regroup or avoid the recreational visitor by moving away from the interaction, the

chance that a strong or severe herd reaction was going to occur was higher. Meaning that the herd was more inclined to move as well. Possibly because bovines have a strong social herd structure, the reaction of one herd member can easily influence the other herd members causing a ripple effect influencing the reaction of the entire herd (Vitale et al. 1986; Bouissou et al. 2001; Madella-Oliveira et al. 2012). Finally humans in a more predictable hiking context (i.e. on trails) were found less threatening than humans hiking off trails (Miller et. al, 2001). Clearly animals pay attention to the behaviour of the approaching human and other herd members, looking for cues as to whether or not the visitor has been spotted or intends to attack.

4.2 Effect of external factors on the behavioural response of bovine species

4.2.1 Breed

Due to the large size and impressive exterior of the "new" breed Tauros, with bulls reaching 1.80 meters shoulder height and horns up to a meter long (Goderie et al. 2013), questions have been raised about public safety in areas where they are introduced. The difference in appearance between large herbivores grazing on public lands can influence public perceptions of the animals, for example longhaired small hornless Galloway cattle are easier perceived as friendly and harmless towards humans, compared to the large horned and unfamiliar Tauros cattle. Previous research by Leruste et al. (2012) has shown breed to be a factor of influence according to the tests focusing on human–animal relationships conducted on veal calves on commercial farms. Furthermore, Murphey et al. (1981) and Boivin et al. (1992) found that there are breed differences in flight distance: dairy cattle have a smaller flight distance than beef breeds, and that flight distance is relatively independent of rearing practices. Our results also show a difference between breeds in their behavioural response towards recreational visitors. There seem to be two groups that differ in their reaction: the Tauros and the Wisent versus the Scottish Highland cattle and the Galloway. The Wisent is a wild undomesticated bovine species while the Tauros is being designed as an ancient wild herbivore originating from domesticated cattle breeds. Tauros displayed more regrouping behaviour and, together with the Wisent, less grazing compared to Scottish Highland cattle and Galloway. Galloway and Scottish Highland cattle were more prone to stay stationary during an interaction with a recreational visitor compared to Wisent with the Tauros fitting in between. It can be argued that regrouping of herd members is a behaviour exhibited by more "wild" bovine species. Tauros and Wisent showed more strong and severe responses and have a greater alert distance which can be attributed to extra vigilance. Perhaps, Wisent and Tauros are more fearful of humans and thus exhibit more avoidance or movement behaviour. In general, the Tauros herds seem to show more "wild" behavioural reactions than the current domesticated breeds but less than the truly wild Wisent. These effects might be due to genetic differences but this could be partially due to a lower level of contact with humans rather than a genetic effect. As calves from those different breeds were raised in similar conditions, these effects might be due to genetic differences, but further research is needed to defend this hypothesis.

Because the Tauros herds are part of an extensive breeding program, the program itself might influence the behavioural responses to recreational visitors. Due to the breeding program the current herds are "artificially" composed and regularly disturbed by the introduction or removal of new unrelated individuals, disrupting the established social hierarchy. Therefore, the relatively new herds have less stable internal dominance structures which can influence behavioural responses to recreational visitors. The same is true for the Wisent which relatively recent formed a new herd

with new unrelated individuals being introduced regularly. This could be an alternative explanation for the increased vigilance displayed by Tauros and Wisent. An individual that is introduced in a new and unfamiliar habitat with an unfamiliar herd needs time to get habituated to the situation, furthermore the herd needs time to re-establish the social hierarchy. Ideally land managers should strive towards stable herds including strong bonds between herd members and a clearly defined social structure. This can be expected to make behavioural reactions more predictable.

4.2.2 Habitat

Habitat size and vegetation structure have been proven to influence the reaction of different bovine species to recreational visitors. Ungulates in more open habitats were found to flee more readily than ungulates in closed wooded habitats (weak effects and highly heterogeneous) (Stankowich 2008). In contrast, our results showed more strong and severe responses occurring in covered vegetation structures where the animals were more easily startled by the presence of the visitor. Large vegetation structures like trees and shrubs can obscure vision of the herd resulting in a delayed detection of the recreational visitor, but no difference in alert distance or response time for habitat cover could be identified. Habitat size also appears to have an effect on the behavioural response of different bovine species, there was a slight trend in increasing response times with increasing habitat size. This can possibly be an effect of operational flaws of the simulation test itself: in large open habitats the observer can start videotaping the interaction from a greater starting distance, thus causing the recreational visitor to need extra time before reaching the herd and starting the interaction. On the other hand, in large habitat with an open vegetation structure we would expect the herd to have a decreasing response time because the visitor can be noticed from a greater distance. Knowledge on how habitat size and vegetation structure influences behavioural reactions can aid in management practices aimed to reduce the occurrence of strong and severe reactions in a specific natural area. By avoiding trees and shrubs obstructing view of a recreational trail for instance can help reduce more severe behavioural reactions in bovine herds, thus limit unwanted interactions and reducing stress subsequently improving animal welfare. To be able to pinpoint the precise effects of habitat cover and habitat size on behavioural reactions of bovine species to different types of recreational visitors, further investigation is recommended.

Another factor is a process called habituation which occurs in these mammals. The process of habituation could not be tested but needs to be taken into account when interpreting the results correctly. Previous research has showed populations in areas with higher levels of human traffic exhibiting reduced wariness, probably caused by habituation effects or a lack of alternative sites to move to (Barry 2014; Taylor and Knight 2003). It can be hypothesized that relatively new herds (like the Tauros and the Wisent) can get acquainted to different types of recreational visitors and subsequently change behavioural responses over time. To our knowledge, no comprehensive research on the effects of different recreational pressures and the occurrence of habituation in different bovine species under semi-wild conditions has been conducted so far.

4.2.3 Time of day

Time of day has been found to be important in predicting response distances. Mule deer (*Odocoileus hemionus)* alert distance was found to be greater in the evening, but for American bison *(Bison bison)* flight distance and mule deer distance moved were greater in the morning (Stankowich 2008; Graham et al. 2010). Also, in hunted populations individuals appeared to be more fearful at dusk and dawn compared to other times of the day (Lansade & Bouissou 2008).

This coincides partly with our results which show that later in the day the chance of a more strong and severe behavioural reaction to a recreational visitor increases. This can be due to their natural daily behavioural rhythm, or a possible accumulation effects occurs when a herd has been mildly disturbed during the day. At the end of the day they are more agitated or more prone to flee the situation. This is also shown by the fact that in the late afternoon and evening the response time of the first individual decreased compared to morning and midday, indicating that bovine species are more vigilant later in the day. Understanding the influence of the factor time of day on behavioural reactions can again aid land managers in decision making concerning recreational activities in natural areas supporting herds of large herbivores. By for instance restricting certain recreational activities that create big disturbances (e.g. noise by motorbikes) to later times in the day, unwanted interactions can possibly be minimized and unnecessary disturbance of the bovine herds can be eliminated.

It is important to keep in mind that we have no tests performed really early in the morning (dusk) nor really late in the evening. Therefore, we only could demonstrate an effect of time between 10 am and 6 pm during the day. A larger time range and more data would allow for testing smaller time categories and thus give a more detailed view of the effects of time of day.

4.2.4 Herd size

Taylor and Knight (2003) showed that larger groups size tended to increase response distances. Group composition was relatively unimportant in predicting wildlife responses except for flight distance and distance moved which increased as the number of the males increased. Stankowich (2008) also found a very weak overall effect of larger groups to showing greater flight responses. This was hypothesized to be the result of increased safety in numbers, more individuals meaning more eyes on the lookout and a greater chance of an individual spotting a visitor or a predator early. This counteracts our results, which show response time increased slightly with increased herd size and alert distances decreased slightly with an increase in herd size. For every unit increase in herd size, we found that the fraction of strong and severe reactions to an interaction with a recreational visitor decreased slightly (1,4%). It could be hypothesized, the safety in numbers meant that the individuals feel more confidence when in a larger herd thus reducing vigilance and decreasing the occurrence of strong and severe reaction and alert distance. Because of the limited amount of herds included in the research, our results are influenced by breed and habitat since larger herds are normally in habitats of larger size. Furthermore, the larger herds that were part of the research represented older herds with a strong social structure (for instance the Scottish Highland herd in the Herperduin natural area), this in contrast to the relatively new and much smaller Tauros herds.

4.3 Can we identify the importance of different factors influencing bovine behaviour?

Different factors have been shown to influence behavioural reactions by different bovine species to recreational visitors. It has been suggested by Stankowich (2008) that environmental factors and experience with humans and their recreational activities have significant impacts on ungulate behaviour. However results are hard to generalize for bovine species due to the interactive effects of different factors: while some effects are found to be ubiquitous (e.g. approaching behaviour), others are species or population specific (e.g. group size).

Our research showed the strongest independent factors influencing behavioural reactions were breed, time of day and to a lesser degree habitat type. Breed (p value 0,002) and time of day (p value 0,003) have a similar effect and have been found the strongest drivers of severity of a herd reaction. As previously discussed questions still remain surrounding the exact nature of breed effects (section 4.2.1.). This illustrates the need for more detailed scientific research to increase current knowledge of possible effects of breed and time of day on behavioural reactions to recreational visitors. A better understanding of the different effects can aid in informed decision making processes concerning recreation in natural wilderness areas.

4.4 Are there differences in response between individual Tauros herds?

The Tauros herds were not uniform in their percentage of strong and severe behavioural reactions to recreational visitors. De Grauss and Keent displayed significant lower amounts of strong and severe responses, whereas the Loozerheide and Tungelrooyse Beek showed significantly higher percentages of strong and severe reactions. The differences between the individual herds can be partly attributed to the above describes influencing environmental factors (differences in habitat cover and size) as well as the difference in genetic composition of the individual Tauros herds. Breed was shown to be the strongest influencing external factor but the specific effects are still unknown. Furthermore, effects of differences in management practices as well as the effects of the breeding program itself as previously discussed (e.g. differences in background, genetic composition, herd structure, for explanation see section 4.2.1.) all possibly contribute to the occurrence of different behavioural reactions. Again, a better understanding of the different effects can aid in informed decision making processes concerning the different Tauros herds.

5. Conclusions

The most common initial reaction of the investigated bovine species to a recreational visitor was to look up at the novelty in their environment. The second most common behaviour displayed was to regroup with other herd members. Situations in which the recreational visitor was approached by cattle only occurred in 5% of the interactions simulated.

Concerning visitor safety issues: no aggressive behaviour towards recreational visitors was documented during the entire field work period.

No differences in behavioural reactions of different bovine species to different types of recreational visitors were found. Although, the presence of a jogger seems to trigger the animals to feel the need to move more than the walker and the walker with a dog. Contrary to common believe, bovine species did not react differently to the presence of a dog and thus seemed not to identify the domestic dog on a leash with their natural predator the wolf. This holds for our test dog: a non-barking nor growling single dog. To determine the effect of multiple dogs, dogs that interact with the bovine species and dogs of-leash, more research is needed.

Calves and especially yearlings are in an important explorative developmental stage increasing the chance of approach behaviour occurring when interacting with recreational visitors. This needs to be taken into account when introducing herds with a large percentage of young individuals. Managers may be able to overcome misinterpretations of aggressiveness and negative perceptions and fear of cattle by the public via education on cattle behaviour. Knowledge on how to distinguish between the curiosity of a yearling from a display of agitation can greatly improve the relationship between the public and large semi-wild herbivores.

Tauros behaviour is, as might be expected, intermediate between the behavioural reactions of a wild herbivore (Wisent) and the domesticated cattle breeds (Scottish Highland cattle and Galloway). Results show that both Tauros and Wisent have greater alert distances and display more vigilance and wariness towards recreational visitors. They are more prone to move and avoid an interaction compared to the more domesticated breeds.

Breed and time of day were shown to be the strongest influencing factors followed by type of habitat. Because all of these influencing factors are partly confounded and because of the relatively limited sample size of the research, more investigation is needed to pinpoint precise effects. Increased insight in the interactive effects of different environmental factors can aid land managers in decision making processes.

The Tauros herds showed that differences in behavioural reactions towards recreational visitors existed between individual herds. This can partly be attributed to the influence of external factors like: habitat, herd size, social herd structure, history of individual herd members, differences in genetic composition of herd members as a result of the breeding program, effects of the breeding program itself and habituation effects caused by recreational pressure of the natural area.

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