ESTONIAN UNIVERSITY OF LIFE SCIENCES
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ANIMAL SPECIES SCAVENGING ON WILD BOAR CARCASSES ON ISLAND HIIUMAA (ESTONIA)

METSSEA KORJUSTEST TOITUVAD LOOMA JA LINNULIIGID HIIUMAAL (EESTIS)

Final Thesis
Curriculum in Veterinary Medicine

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Understanding the importance of wildlife in disease distribution dynamics has increased. Wildlife is a significant source of infections for livestock, companion animals and even for humans. Among wildlife, there are several modes of disease transmission, one being through scavenging. Scavenging behaviour is very common among vertebrates in both avian and mammalian species and it is an important part of ecosystem. Scavenging is not only beneficial, but it can also pose a health risk by ingesting pathogens and toxic by-products of microbial metabolism. Potential role of scavenging in disease transmission has been studied marginally.

Wild boar is a facultative scavenger. There has been a steep increase in the wild boar population in Europe. Wild boar has been noted being an important host of agents of some diseases such as African swine fever, bovine tuberculosis, tularaemia, and brucellosis. Differences in scavenging behaviour of wild boar has been noted around Europe: in some areas, cannibalism has been detected whereas in other areas only interspecies scavenging in wild boar has been shown.

The general objective of this study was to describe scavenging behaviour of wildlife on wild boar carcasses in Hiiumaa (Estonia). Specific aims were to find out, which animal species are in contact with or scavenge wild boar carcasses and to investigate if intraspecies scavenging occurs among wild boar in Hiiumaa. With help of camera traps 17 vertebrate species were identified in proximity of wild boar carcasses placed in the forest, out of which 11 were in direct contact with the carcass. Common raven (*Corvus corax*), red fox (*Vulpes vulpes*), raccoon dog (*Nyctereutes procyonoides*), and wild boar (*Sus scrofa*) were the four most common species in contact. There were no clear signs of cannibalism among wild boar observed in this study.

Keywords: Scavenging, wild boar, wildlife, African Swine Fever

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Metsloomade tähtsuse mõistmine haiguste leviku dünaamikas on suurenenud. Metsloomad on oluliseks nakkuste allikaks produktiiv- ja seltsiloomadele ning isegi inimestele. Haiguste edasikandumise viise metsloomade hulgas on mitmeid, millest üks on raipesöömine. Raipesöömine on selgroogsete seas väga levinud nii lindude kui ka imetajate puhul ning see on oluline osa ökosüsteemist. Raipesöömine ei ole mitte ainult kasulik, vaid see võib kujutada ka terviseriski, kui seeläbi neelatakse ka patogeene ja mikroobide mürgiseid metaboliite. Raipesöömise võimalikku rolli haiguste edasikandumises on uuritud vähe.

Metssiga on fakultatiivne raipesööja. Euroopas on järsult suurenenud metssigade populatsioon. Metssigu on täheldatud olevat mõne haiguse, näiteks sigade aafrika katkuveiste, tuberkuloosi, tulareemia ja brutselloosi tekitajate oluline peremeesloom. Euroopas on täheldatud erinevusi metssigade raipesöömis-käitumises: mõnedes piirkondades on tuvastatud kannibalismi, samas kui teistes on täheldatud ainult metssigade toitumist teiste liikide korjustest.

Selle uuringu üldine eesmärk oli kirjeldada metsloomade raipesöömis-käitumist metssigade rümpadel Hiiumaal. Konkreetsed eesmärgid olid välja selgitada, millised loomaliigid on kokkupuutes metssigade korjustega ja toituvad neist ning uurida, kas Hiiumaa metssigade hulgas esineb liigisisest raipesöömist. Rajakaamerate abil tuvastati 17 selgroogset liiki metsa paigutatud metsseakorjuste läheduses, millest 11 olid korjusega otseses kontaktis. Ronk (*Corvus corax*), punarebane (*Vulpes vulpes*), kährikkoer (*Nyctereutes procyonoides*) ja metssiga (*Sus scrofa*) olid neli kõige tavalisemat liiki, kes olid kokkupuutes korjusega. Selles uuringus selgeid märke kannibalismist metssigade seas ei tuvastatud.

Märksõnad: Raipesöömine, sigade Aafrika katk, veiste tuberkuloos, tulareemia, brutselloos, metssiga, elusloodus

TABLE OF CONTENTS

LIST OF ABBREVIATIONS AND KEY TERMS

ASF	African swine fever
ASFV	African swine fever virus
bTB	Bovine tuberculosis
LNs	Lymph nodes
OIE	World Organization of Animal Health
MTBC	Mycobacterium tuberculosis complex
NSAID	Nonsteroidal anti-inflammatory drug

INTRODUCTION

“One Health” approach combines the human, animal, and environmental health together. While thinking about animal health, not only domestic animals but also wild animals should be taken into consideration. Therefore, the role of wildlife in transmission of infectious diseases shouldn’t be underestimated as wildlife can be a potential source of infection not only for domestic animals but also for humans. Scavenging has been considered as a potential way of transmission in wildlife.

Scavenging occurs frequently among wildlife and it is an important part of ecosystem (DeVault *et al.*, 2003; Focardi *et al.*, 2017). There is a gap of knowledge regarding scavenging behaviour among vertebrates possibly due to human loathing towards rotted material and challenges to identify animal carcasses as potential food resources for vertebrate animals (DeVault *et al.*, 2003). Vertebrate scavengers can be divided into obligate scavengers (vultures) and facultative scavengers (Markandya *et al.*, 2008).

There are several variables affecting scavenging behaviour such as species of both scavenger and carcass, temperature and time of the day (DeVault *et al.*, 2003; Moleón *et al.*, 2017; Young *et al.*, 2014). Cameras are most common method of investigation when studying scavenging (e.g. Carrasco-Garcia *et al.*, 2018; Focardi *et al.*, 2017; Gomo *et al.*, 2020; Peisley *et al.*, 2017; Probst *et al.*, 2019). Scavenging isn’t risk-free and scavenger might get sick when consuming the carcass by obtaining pathogen and toxic by-products of microbial metabolism (Blumstein *et al.*, 2017).

Studying of diseases in wildlife is challenging because detection of sick and dead animals is not as straightforward as in humans and domestic animals (Wobeser, 2006). Scavenging is one possible way of disease transmission among wildlife. Scavengers can either prevent or increase spreading of diseases depending on the situation. Factors related to transmission of diseases through scavenging include pathogen, territory, species of both scavenger and carcass .(Carrasco-Garcia *et al.*, 2018; Vicente and VerCauteren, 2019; Wobeser, 2006). Even so, most studies related to scavenging on vertebrates have been observational studies and mainly hypotheses about the role of scavenging in disease transmission has been suggested (Muñoz-Lozano *et al.*, 2019).

The role of wild boar in spreading of diseases, especially in case of African swine fever (ASF) has been a hot topic in Europe since 2007 when African swine fever virus was detected for the first time in Eastern Europe and it has been noted that wild boars have had an important role in the quick spreading of the disease (Cwynar *et al.*, 2019; Schulz *et al.*, 2020). Intraspecies scavenging among wild boar has been suggested as a possible way of transmission however the scavenging behaviour of wild boar has not been studied much and it seems that the behaviour differs between countries (Cukor et al., 2020a; Merta et al., 2014; Probst et al., 2017).

The general objective of this study was to describe scavenging behaviour of Estonian wildlife on wild boar carcasses with special emphases on wild boar behaviour to understand their role in the spread of ASF in wild boar populations.

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1. LITERATURE REVIEW

1.1. Scavenging

Scavenging can be defined as a process in which an animal is consuming carcass by shredding, disconnecting, chewing or breaking down soft tissue and bones (Young *et al.*, 2015). Scavenging is a vital part of ecosystem and present everywhere (Focardi *et al.*, 2017). Carcasses consumed by scavengers are commonly from animals which have died due to malnourishment, disease, exposure, parasites or injuries (DeVault *et al.*, 2003). In addition, scavenging may occur due to kleptoparasitism, a form of competition that involves theft of readily killed prey from another animal (Iyengar, 2008).

Scavengers can be divided into vertebrate and invertebrate scavengers and further into either obligate or facultative scavengers (Muñoz-Lozano *et al.*, 2019). Vertebrate scavengers are in response of consuming the majority of the carcass (DeVault *et al.*, 2003). Decomposition of carcasses occurs quickly and as a result there is only limited availability of carrions for scavengers to consume (DeVault *et al.*, 2003). That being the case enlightens why obligate scavenger are rather rare. However, almost all carnivore vertebrates should be regarded as facultative scavengers because they frequently consume fresh carcass when found (DeVault *et al.*, 2003).

1.1.1. Scavenging behaviour

It has been noted that there are differences in scavenging behaviour between species concerning the preferred time of the day, atmospheric condition and stage of decomposition (Young *et al.*, 2014). The common tendency of scavenging increases while temperature decreases, raccoon dog (*Nyctereutes procyonoides*) being an exception (Selva *et al.*, 2005). Scavenging pattern varies between herbivore and carnivore carcasses: herbivore carcasses are mainly consumed by vertebrate scavengers, whereas carnivore scavengers were avoided by mammalian carnivores particularly another organism of the same species (DeVault *et al.*, 2003; Moleón *et al.*, 2017). Scavenging occurs most often when carcass is still fresh (Probst *et al.*, 2019; Young *et al.*, 2014).

1.1.2. Availability of carcasses

Availability of carcasses for scavenging varies throughout the year (DeVault *et al.*, 2003). In winter, frozen carcasses may be impossible to break into for some species unless another species opens them first (Selva *et al.*, 2005). On the other hand, during the winter, decomposition rate of the carcass is decreased and simultaneously accessibility to main food resources may be limited consequently increasing scavenging (Young *et al.*, 2014).

Carrions of larger animals seem to be consumed more often by vertebrate scavengers compared to smaller animals such as rodents and small birds because smaller animals regularly die in cavities, burrows and other locations difficult to access by vertebrate scavengers whereas larger animals often die in locations easier to approach (DeVault *et al.*, 2003). Carcass may be removed rapidly by scavengers therefore being impossible to find, especially in case of smaller carcasses or when only few animals die (Wobeser, 2006).

1.1.3. Methods of investigation

Camera traps are frequently used when scavenging is investigated (e.g. Focardi *et al.*, 2017; Peisley *et al.*, 2017; Carrasco-Garcia *et al.*, 2018; Probst *et al.*, 2019; Gomo *et al.*, 2020). Also, bite marks on bone surfaces can be used to determine the species scavenging (Focardi *et al.*, 2017; Young *et al.*, 2015). Other direct observations can be used also, including tracks in the snow, feathers and faeces to determine species that have visited on carcass (Selva *et al.*, 2005).

Furthermore, scavenging patterns may variate between species. For instance, wolves open the abdominal cavity at first and eat some internal organs, namely liver, heart and lungs, but not intestines whereas wild boar consumes the carcass (including the intestines) without any particular order (Focardi *et al.*, 2017). Because faecal remnants of both killed and scavenged carcasses are almost alike, scat analysis cannot be used to determine whether the consumed carcass was killed or scavenged (DeVault *et al.*, 2003).

1.1.4. Avian scavengers

There are numerous avian facultative scavenging species including corvids (such as ravens and crows), storks, gulls, eagles, hawks and kites whereas vultures are the only obligate vertebrate scavengers (Buechley and Şekercioğlu, 2016; Peisley *et al.*, 2017). Avian scavengers can travel great distances compared to mammalian scavengers, who have much more restricted feeding territories and therefore, pathogens surviving through the gastrointestinal tract of vultures have the potential to spread very efficiently (Houston and Cooper, 1975). Avian species have some advantages over mammal detecting carcasses such as a panoramic view, an enthusiastic sense of vision and social information transfer (Probst *et al.*, 2019). Avian scavengers scavenge mostly soft tissue (Young *et al.*, 2014).

Vultures are not found all around the globe and their populations are declining, therefore the role of other scavenging avian in carcass breakdown needs to be taken into consideration (Peisley *et al.*, 2017). In India, Pakistan and Nepal, decline in vulture populations is almost exclusively due to diclofenac (a nonsteroidal anti-inflammatory drug, NSAID) which is extremely toxic to vultures, hence allowing increased numbers of feral dogs infected by rabies scavenge on cattle carrions and thus spreading rabies (Markandya *et al.*, 2008).

1.1.5. Mammalian scavengers

There are several mammalian scavenger species in Europe and differences in species between countries. In Britain, red fox (*Vulpes vulpes*), Eurasian badger (*Meles meles*) are most common mammalian species detected scavenging (Young *et al.*, 2015). A study performed in Germany revealed red fox and raccoon dog scavenging on wild boar carcasses and in addition six mammalian species were considered as potential scavengers i.e. wild boar (*Sus scrofa*), raccoon (*Procyon lotor*), marten (*Martes sp*.), polecat (*Mustela putorius*), water vole (*Arvicola terrestris*), and domestic dog (*Canis familiaris*) (Probst *et al.,* 2019). Six species were detected in a study in Norway scavenging reindeer that are short-tailed weasel (*Mustela erminea*), least weasel (*Mustela nivalis),* European pine marten (*Martes martes*), red fox, wolverine (*Gulo gulo*) and arctic fox (*Vulpes lagopus*) (Gomo *et al.*, 2020).

1.1.6. Wild boar as a scavenger

1.1.6.1. Distribution of wild boar

Wild boar is a native species in Eurasian and North Africa and additionally it has been introduced to all other continents expect Antarctica (Barrios-Garcia and Ballari, 2012). The Eurasian wild boar is widespread along Europe and there has been a sharp increase in the population (Meier and Ryser-Degiorgis, 2018).

Wild boars are social animals and their herd regularly contains closely related females and their offspring while males live generally unaccompanied but sometimes, they form packs consisting of males only (Jensen, 2002) The size of a home range is mostly influenced by the accessibility of food, in addition there is difference between sexes as males are having larger home range compared to females. In principle, wild boars are diurnal animals but are easily shifted to nocturnal animals, especially in areas where they are hunted. Exploratory behaviour, in particular rooting, smelling and chewing, is natural for wild boars.

1.1.6.2. Diet composition

Wild boars are omnivorous animals and their diet is rather flexible (Ballari and Barrios-García, 2014). The diet composition of wild boar varies significantly in native and introduced ranges. Wild boar diet is affected by availability of food, energy needs, seasonal differences, and geographical variations. Plant material dominates the diet of a wild boar being approximately 90%. In both ranges, native and introduced, wild boar diet is dominated by material of a plant origin (being approximately 90%), but animal matter and fungi form a larger proportion of the diet in the introduced range compared to native range.

1.1.6.3. Wild boar scavenging behaviour

There are differences in in wild boar scavenging behaviour across Europe (Table 1.). A study conducted in Germany, observed wild boar scavenging in red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*), but there were no clear signs of intraspecies scavenging however direct contact was recorded (Probst *et al.*, 2017). In Czech Republic, cannibalism of wild boar was noted in some cases although direct contact with the carcass was more frequent (Cukor *et al.*, 2020a). In addition, a study performed Poland revealed wild boar consuming tissues of deer and wild boar during cold season (Merta *et al.*, 2014).

Table 1. *Comparison of wild boar scavenging behaviour based on studies conducted in Czech Republic, Germany and Poland* (Cukor *et al.*, 2020a; Merta *et al.*, 2014; Probst *et al.*, 2017)

	Interspecies scavenging	Direct contact with wild boar carcass	Intraspecies scavenging
Czech Republic	*Not studied*	*Yes*	*Yes*
Germany	*Yes*	*Yes*	*No*
Poland	*Yes*	*Not studied*	*Yes*

1.1.6.4. Role of wild boar in spreading diseases

Wild boars are reservoirs for numerous viruses, bacteria and parasites that can be transmitted to domestic animals and humans (Meng and Lindsay, 2009). Freely moving wild boars are deliberated as a hazard to the swine industry because domestic swine and wild boar are susceptible to the same pathogens and are able to transmit infections to each other, e.g. ASF (Meier and Ryser-Degiorgis, 2018). In addition, wild boar may also be a source of infection also for bovine (bovine tuberculosis), domestic pets (Aujeszky's disease) and even humans (hepatitis

E, leptospirosis, trichinellosis and foodborne diseases caused by bacteria) (Meier and Ryser-Degiorgis, 2018; Meng and Lindsay, 2009).

Disease surveillance in both domestic swine and wild boar, biosecurity on farms and sustainable wild boar management are vital when preventing introduction and transmission of pathogens between wild boar and domestic swine (Meier and Ryser-Degiorgis, 2018). Adequate disposal of hunting remains is suggested being additional method in control and prevention of diseases between wild boar and other animal species (Cano-Terriza *et al.*, 2018).

1.2.Role of scavenging in disease transmission

1.2.1. Exposure to disease agents by scavenging

Scavengers are at risk to be obtain to pathogens and toxic by-products of microbial metabolisms when consuming carcass (Blumstein *et al.*, 2017). Scavenger may get a clinical disease, or it can be asymptomatic carrier of the pathogen, depending on several factors such as susceptibility of the disease, the infectious dose, health status of an animal (Hestvik *et al.*, 2019; Sánchez-Vizcaíno *et al.*, 2015). Possible bacteria colonizing carcass and producing toxic by-products dangerous to vertebrate scavengers include *Clostridium perfrigens, Clostridum botulinum, Escherichia coli, Staphylococcus aureus, Shigella dysenteriae, Salmonella typhi* and *Bacillus stearothermophilus* (DeVault *et al.*, 2003).

Scavengers may be able to reduce the risk of getting diseases from carrions by avoiding rotten food, having a specialized microbiome, having enhanced immunologic defences and maintaining low gastric pH to eliminate pathogens (Blumstein *et al.*, 2017). Interspecific spread of disease through scavenging is more common whereas intraspecific transmission of disease is considered to be less common (Wobeser, 2006). The carnivore carrion-avoidance hypothesis suggests that mammalian carnivores avoid scavenging on carnivore carcasses, particularly at the intraspecific level, to prevent the risk of disease transmission (Moleón *et al.*, 2017; Muñoz-Lozano *et al.*, 2019).

1.2.2. Detection of disease in wildlife

Detection of sick and dead individuals of wildlife animals is challenging compared to humans and domestic animals, because wild animals are rarely observed in detail in terms of their health (Wobeser, 2006). Secondly, wild animals aim to hide their dysfunction or illness when possible. In addition, following the course of the disease is almost impossible among wildlife, unless captured and marked, making it hard to know did the animal recover, remained disabled or died. Finally, detection of the carcass after death can be difficult.

Searching of the disease in wildlife can be done by searching for sick or dead animals, causative agent, physiologic response to the causative agent of the disease of the evidence of the disease or the causative agent in other species than the primary species (Wobeser, 2006).

1.2.3. Spreading of diseases through scavenging

Wildlife species can act as reservoirs and be asymptomatic carriers of diseases (Hestvik *et al.*, 2019). Obligate scavengers and reservoir hosts of disease are at higher risk of infection compared to other wildlife species (Vicente and VerCauteren, 2019). There is also an epidemiological link between wildlife and several diseases in livestock (Godfroid *et al.*, 2013).

Scavenging has been considered as a potential predisposing factor for transmission of some infectious diseases such as tuberculosis, brucellosis African swine fever (ASF), anthrax, tularemia (Hestvik *et al.*, 2019; Probst *et al.*, 2019; Vicente and VerCauteren, 2019). Most commonly pathogens which are spread through scavenging, for instance members of Mycobacterium tuberculosis complex (MTBC) causing bovine tuberculosis (bTB) are passively ingested (Vicente and VerCauteren, 2019). Furthermore, previous opening of the carcass by scavengers may allow the pathogens (namely *Bacillus anthracis* causing anthrax, a severe zoonotic disease) to depart the carcass and persevere in the environment or allow the spread by vectors (Vicente and VerCauteren, 2019).

On the other hand, it has been suggested, that in some cases scavenging could prevent spreading of the disease instead (Carrasco-Garcia *et al.*, 2018). One explanation being that most pathogenic organisms in carcasses are not able to survive passageway through the strongly acidic alimentary system of vultures (Houston and Cooper, 1975). In addition, scavengers may decrease the transmission of brucellosis by reducing the time of an infectious material remaining in the environment (Cook *et al.*, 2004).

Houston and Cooper (1975) described four different ways of transmission of pathogens by vultures, which are facultative scavengers:

1) pathogen causing clinical or sub-clinical infection and is discharged in the secretions or excretions of the vulture or spread by vectors;
2) pathogen transferred mechanically on the feathers or feet;
3) pathogen is regurgitated with pellets from crop;
4) pathogen travels through the gastrointestinal tract and is detected in the faeces.

1.3. Role of scavenging in transmission of specific diseases

1.3.1. African swine fever

ASF is a contagious viral disease of both wild and domestic swine. The causative agent is African swine fever virus (ASFV) which is a large, double stranded DNA virus and belongs to family Asfarviridae, genus Asfivirus. (Galindo and Alonso, 2017). ASF was described for the first time in Kenya, East Africa in 1921 (Eustace Montgomery, 1921).

ASF is lethal and causes haemorrhagic fever (Penrith and Vosloo, 2009). It is a notifiable disease and must be reported to the World Organization of Animal Health (OIE) (Sánchez-Vizcaíno *et al.*, 2015).

1.3.1.1. Transmission

Transmission of ASFV can occur by several different ways including by direct contact, by consuming infected meat, by arthropod vectors (genus *Ornithodoros*) and by indirect contact via bedding, feed, tools, clothes, footwear or secretions from an infected animal including blood, faeces, urine and saliva containing ASFV (Penrith and Vosloo, 2009).

Infected wild boars have an important part in the current ASF epidemic in Eastern Europe (Schulz *et al.*, 2020). Carcasses of infected wild boar are an possible way of ASFV transmission, but localization of carcasses is a challenge as it takes time and finding of carcasses can be difficult (Cukor *et al.*, 2020b; Probst *et al.*, 2017). In Czech Republic majority of the wild boar carcasses infected with ASFV were found in forests, suggesting that wild boars favour places with adequate cover, silence, rest and lower densities of other species as their deathbed choice (Cukor *et al.*, 2020b).

There are four different epidemiologic cycles of ASF described: sylvatic, tick-pig, domestic and wild boar-habitat cycle (Chenais *et al.*, 2018). In sylvatic cycle, ASFV is transmitted among warthogs (*Phacochoerus*) and soft ticks (*Argasidae*) without causing the disease in warthogs. In case of the tick-pig cycle, the virus mingles between soft ticks and domestic swine. In domestic cycle, the transmission occurs between domestic swine and pig-derived products such as pork, blood, bones, and lard. Most recently described cycle is the wild boar-habitat cycle which is characterized by both direct transmission between infected and susceptible wild boar and indirect transmission via carcasses.

1.3.1.2. Clinical disease

The clinical presentation and pathological changes of ASF are depended on various factors: virulence of the virus isolate, route and dose of infection and characteristics of the host (Sánchez-Vizcaíno *et al.*, 2015). ASF is divided into different forms: peracute, acute, subacute, chronic based on the virulence of the viral strain and clinical manifestation. In case of a low dose of virus infection in ASF naïve farm, there is no high mortality nor typical clinical signs in the beginning, excluding fever and deaths with some haemorrhagic lymph nodes. Due to growing viral circulation some days later, there can be more severe sings with higher mortality together with distinctive clinical signs and pathological changes. Thus, every dead pig in a high-risk area with fever should be examined for ASF.

1.3.1.3. Prevention and control

There is currently no vaccine nor treatment available for ASF and therefore preventive measures such as surveillance, epidemiological investigation, stamping out, biosecurity and controlling movement of animals have a vital role in controlling the disease (Gallardo *et al.*, 2019). Studies have shown that carcasses of infected wild boar are important way of transmission of the disease and therefore removal of carcasses from the environment is suggested being an effective method to control the spread of the disease (Cukor *et al.*, 2020b). In Estonia, in order to eliminate the disease, the concentration has been on both active and passive surveillance in wild boar, meaning testing of all found dead wild boars for ASFV by PCR and testing all hunted wild boars for ASF by PCR and for ASF specific antibodies, respectively (Schulz *et al.*, 2020).

1.3.1.4. Distribution in Europe

ASF was established in Europe for the first time in Portugal in 1957 and it remained endemic until 1995 when it was eradicated from mainland Europe, whereas in Sardinia island, ASF has been endemic sine 1978 (EFSA, 2010). The ASFV was detected in Georgia in June 2007, after which it has spread quickly in Eastern Europe (Cwynar *et al.*, 2019). In 2014, ASF was found in Baltic countries and Poland (EFSA *et al.*, 2017). First cases of ASF in Belgium were confirmed in 2018, after hunters discovered several dead wild boars located near to each other (Linden *et al.*, 2019). In 2020, spreading of ASF has continued in Europe. The first case of ASF in Greece was confirmed in February 2020 when ASFV was discovered in dead fattening pig in a backyard farm (OIE, 2020). ASF was detected on the first time in wild boar in Germany on September 2020 (Sauter-Louis *et al.*, 2020).

1.3.1.5. African Swine Fever in Estonia

ASF was detected in Estonia for the first time in September 2014 on a deceased wild boar (Nurmoja *et al.*, 2017). First cases of ASF in Estonia were reported in wild boar, whereas first ASF outbreaks in domestic pig farms were in 2015 (Schulz *et al.*, 2020). ASF has been detected in all territories of Estonia apart from the island of Hiiumaa (Schulz *et al.*, 2019). Last domestic disease outbreak was in October 2017, after which the disease has been found only from wild boar populations (Schulz *et al.*, 2020).

1.3.2. Bovine tuberculosis

Mycobacterium bovis and associated members of the Mycobacterium tuberculosis complex (MTBC) are causative agents of bTB and can infect both domestic and wild animals and in addition humans (Gortázar *et al.*, 2012). In addition to zoonotic potential, bTB has significant economic influence in production of livestock due to restrictions in animal movement and expenses of testing and culling (Cano-Terriza *et al.*, 2018). There are four different excretion routes of MTBC: oronasal, bronchial-alveolar, fecal and urinary (Santos *et al.*, 2015).

1.3.2.1. Transmission through scavenging

Scavenging should to be considered as a possible way of transmission of bTB (Carrasco-Garcia *et al.*, 2018). Consumption of contaminated materials (in case of scavenging: not only carcass, but also hunting gut-pile) increases the risk of bTB infection (Gortazar *et al.*, 2011). The potential role of scavenging in the transmission of bTB has been studied in New Zealand, suggesting that scavenging may facilitate intraspecific and interspecific transmission ferrets

(*Mustela furo*), possums (*Trichosurus vulpecula*) and feral cats (*Felis domesticus*) (Ragg and Moller, 2000). In Spain, scavenging behaviour of wild boar has been suggested as a potential risk factor for transmission of bTB (Carrasco-Garcia *et al.*, 2018).

1.3.2.2. Wildlife hosts in Europe

Around Europe, there are probable local alterations in bTB maintenance hosts: the Eurasian badger in Great Britain and Ireland, the Eurasian wild boar in the Iberian Peninsula and both red deer and fallow deer (*Dama dama*) in numerous European areas (Gortázar *et al.*, 2012). Wild boar appears to act as true wildlife reservoir of bTB in Spanish Mediterranean ecosystem, nevertheless scientific evidence is controversial outside Spain and wild boar is considered often as a spillover or dead end host (Naranjo *et al.*, 2008).

1.3.2.3. Macroscopic lesions in wildlife hosts

Knowledge about distribution and characteristics of lesions aids to determine the importance of wildlife species as a reservoir host of bTB (Martín-Hernando *et al.*, 2007). Tuberculous lesions are frequently seen in lymph nodes (LNs), and in some cases, internal organs (Zanella *et al.*, 2008). Animals with generalised lesions have higher probability to excrete MTBC by several routes and thus spread the disease (Martín-Hernando *et al.*, 2007).

Wild boar may have either local bTB meaning lesions are limited to one anatomical region or generalized bTB (Martín-Hernando *et al.*, 2007). Zanella *et al.* (2008) compares patterns of lesions in bTB between wild boar and red deer in France, noticing that red deer had lesions in the organs and LNs, whereas in wild boar, lesions were primarily in LNs. Therefore, they suggested that the role of red deer is more important in intraspecies and interspecies transmission of bTB, while in wild boar transmission would be mostly intraspecies.

In some cases, lesions are not detected in wildlife maintenance hosts even though animal is tested positive for MTBC (Martín-Hernando *et al.*, 2010, 2007). Latent infection without macroscopic lesions is common in badgers and when lesions are detected, they are frequently located in lungs and closely sited LNs (Corner *et al.*, 2012).

1.3.2.4. Prevention and control

The importance of wildlife reservoirs in the presence of bTB in Spain despite mandatory test and slaughter campaigns is progressively recognized (Gortazar *et al.*, 2011). Controlling the bTB infection in wild boar populations is suggested as an important part of eradication of bTB in Spain (Naranjo *et al.*, 2008). The use of oral vaccinations as a one possible way of control bTB in wildlife has been suggested (Gortázar *et al.*, 2012).

1.3.2.5. Distribution in Europe And Estonia

From most parts of Central and Northern Europe, bTB has been eradicated, however bTB is still found in Great Britaind, Ireland, Iberian Peninsula and, in a lower degree in Italy, Greece and in many other countries (Gortázar *et al.*, 2012). In Estonia, last reported case of bTB in domestic animal was in 1986, yet bTB has never been reported in wild animal (OIE, 2015).

1.3.3. Tularemia

Tularemia is a notifiable zoonotic disease caused by Gram-negative bacteria *Francisella tularensis* and it has very extensive host range but principally it is a disease of lagomorphs and rodents (Mörner and Addison, 2001). Whereas lagomorphs and rodents are predisposed to develop clinical disease, predators and scavengers are comparatively resistant and attend as indicators of the disease (Hestvik *et al.*, 2019).

1.3.3.1. Transmission

F. tularensis is highly infectious and can enter the body via numerous ways: by arthropod vectors, by contact with blood or tissues of infected animals, through skin, though conjunctiva, by inhalation of infected aerosols or particles, or by ingestion of contaminated water or meat (Mörner and Addison, 2001). In case of scavengers, ingestion of infected material is suggested being main route of infection (Hestvik *et al.*, 2019). Because tularemia affects mainly rodents and lagomorphs, which are often consumed quickly by scavengers, the biologic cycle of *F. tularensis* in environment is difficult to investigate (DeVault *et al.*, 2003; Origgi *et al.*, 2015). Hunting and scavenging wild animals have the possibility to have latent infection and act as carries of the disease (Hestvik *et al.*, 2019).

Hestvik et al. (2019) described that several species i.e. wild boar, brown bear (*Ursus arctos*), Eurasian lynx (*Lynx lynx*), red fox, grey wolf (*Canis lupus*), wolverine and raccoon dog being natural hosts for *F. tularensis* and therefore can act as indicators of the presence of the disease. Still, the role of scavengers in transmission of tularemia in unclear, as they might serve as potential reservoirs of the disease, but it is also possible that they quickly eliminate the bacteria and hence, prevent the spread of the disease.

1.3.3.2. Clinical signs

In case of an acute disease, the clinical signs include brief, severe apathy followed by fatal septicaemia and the course of the disease lasts approximately 2-10 days (Mörner and Addison, 2001). In case of less sensitive form, there are some nonspecific clinical signs including fever and lethargy followed by possible local inflammation or ulceration at a portal of entry accompanied by enlarged lymph nodes draining the affected area. However, most mammals don’t develop clinical signs, even though developing specific antibodies against tularemia after infection.

1.3.3.3. Prevention and control

Tularemia has several wildlife hosts and ways of transmission, therefore avoidance of spreading in wildlife is challenging. There is no licensed vaccine available at the moment (Carvalho *et al.*, 2020). Active surveillance in both wild and domestic animals and in addition humans is suggested (Hestvik *et al.*, 2015). Early detection of outbreaks in wildlife helps to avoid spreading of disease to humans (Hestvik *et al.*, 2019, 2015).

1.3.3.4. Distribution in Europe And Estonia

In Europe, tularemia is widely distributed in humans, wild animals and also arthropod vectors, however tularemia seem to be emerging especially in Scandinavia and Central Europe (Hestvik *et al.*, 2015). In Estonia, cases of tularemia have been reported in humans, but not in animals (Jõgiste *et al.*, 2005; OIE, 2015).

1.3.4. Brucellosis

Brucellosis in an important zoonotic disease which is widely distributed in mammals, including humans and is caused by bacteria of genus Brucella (Godfroid *et al.*, 2013). In domestic animals, brucellosis is considered as one of the most important infectious cause of reproductive disorders (Megid *et al.*, 2010). In humans, brucellosis is the most common zoonotic disease worldwide causing over 500 000 infections yearly (Godfroid, 2017).

Main pathogenic species of Brucella for livestock are *B. abortus* in bovine, *B. melitensis* in both small ruminants and humans, *B. suis* in swine and *B. ovis* in sheep. *B. abortus* and *B. suis* have been detected also from numerous wildlife species including bison (*Bison bison*), red deer, feral swine and wild boar , the red fox, the European brown hare (*Lepus europaeus*), African buffalo (*Syncerus caffer*), reindeer (*Rangifer tarandus tarandus*) and caribou (*Rangifer tarandus groenlandicus*) whereas *B. melitensis* is seldom found in wildlife (Godfroid *et al.*, 2013).

Wildlife is considered as a potential reservoir of brucellosis in livestock. However, results from different studies are controversial and there is not one unequivocal answer (Godfroid, 2018). In the Greater Yellowstone Area in the North America, transmission of *B. abortus* has been studied between elk, bison and cattle, and only spillbacks from elk have been noted. In Europe, there is only few documented cases of transmission of *B. suis* biovar 2 from wild boar to domestic swine and bovine which are kept outdoors. In Africa, close contact between livestock and wildlife are considered increasing transmission of *Brucella spp*. among them.

1.3.4.1. Transmission

Brucella is excreted in semen, uterine discharges and in milk (Godfroid *et al.*, 2013). Avians have been suggested having a role in transmission of brucellosis either as a "mechanical" vectors or being potential carriers of the disease, however, further studies are required (Wareth *et al.*, 2020). Transmission of brucellosis in wildlife is reduced by scavengers via limiting the time of an infectious fetus remaining in the environment (Vicente and VerCauteren, 2019). Scavenging birds have been suggested being able to spread brucellosis and possibly causing brucellosis outbreaks in livestock (MacDiarmid, 1983).

Maichak *et al.* (2009) describes risk of brucellosis transmission in elk of Western Wyoming. They find eight scavenging species, which are Magpie (*Pica pica*), raven (*Corvus corax*), American crow (*Corvus brachyrhynchos*), golden eagle (*Aquila chrysaetos*), bald eagle (*Haliaetus leucocephalus*), coyote (*Canis latrans*), red fox and gray jay (*Perisoreus canadensis*) consuming elk fetuses, placentas, and fluids. Scavenging removed the material faster from the environment and reduced the contacts of elks with fetuses. Results suggest that scavengers could reduce intraspecific transmission risk of brucellosis in elk.

1.3.4.2. Clinical signs

Brucellosis causes reproductive disorders including abortion, retention of fetal membranes, metritis, subclinical mastitis, infertility, orchitis or epididymitis and is commonly accompanied with infertility or sterility (Godfroid *et al.*, 2013). In chronic cases, articular and peri-articular hygromas are also seen (Godfroid *et al.*, 2013). In humans, brucellosis is called as “undulant fever” characterized by fluctuating fever, tiredness, night sweats, headaches and chills (Cutler *et al.*, 2005; Godfroid *et al.*, 2013).

1.3.4.3. Prevention and control

Protecting the livestock acquiring the disease from wildlife is the main key in disease management (Godfroid, 2017). In southern Spain, the incidence of *B. suis* in wild boar populations is high and poses threat not only to domestic swine but also humans (Meng and Lindsay, 2009). In livestock, prevention, control and eradication of brucellosis can be done by combining testing, vaccination and removing of infected animals (Davis and Elzer, 2002). Stamping-out is also used to control the disease spread (Godfroid, 2017). Efficacy of vaccination against brucellosis in wildlife has not been as good as in domestic livestock (Davis and Elzer, 2002).

1.3.4.4. Distribution in Europe and Estonia

The epidemiological situation varies significantly between European countries and among different animal species (Godfroid and Käsbohrer, 2002). Most Northern European countries are officially free of *B. abortus* and *B. melitensis* whereas in Southern Europe, the situation of brucellosis is less favourable especially in case of *B. melitensis*. *B. suis* has re-emerged in livestock in the beginning of 21st century as a result of spillover from wild boar. In 2014, both bovine and small ruminant brucellosis cases of infected or positive herd have been reported in five Mediterranean countries (Croatia, Greece, Italy, Porugal and Spain) (EFSA and ECDC, 2015). In Estonia, last reported case of *B. suis* in domestic swine and *B. abortus* in domestic cattle were in 1988 and 1961, respectively (OIE, 2015). There are no reported cases of brucellosis in wildlife in Estonia.

ASF, bTB, tularemia and brucellosis in relation to disease transmission through scavenging are summarized in below (Table 2.).

Table 2. *Comparison of ASF, bTB, tularemia and brucellosis and role of scavenging in disease transmission*

Disease	African Swine Fever	Bovine tuberculosis	Tularemia	Brucellosis
Causative agent	African Swine Fever Virus	*Mycobacterium bovis*, members of MTBC	*Francisella tularensis*	*Brucella spp.*
Hosts	Wild and domestic swine	Domestic and wild animals, humans	Mostly lagomorphs and rodents	Domestic and wild animals, humans
Role of scavenging in transmission of disease	Direct contact more important than intraspecies scavenging	Scavenging is a possible way of transmission.	Scavengers are potential reservoirs of the disease, but they may prevent spreading by eliminating the bacteria from the environment	Scavenging removes the infectious material faster from the environment and reduces risk of transmission of the disease

Scavenging is a potentially predisposing factor in transmission of ASF and bTB but limiting factor in transmission of brucellosis whereas in case of tularemia, scavenging may be a limiting factor or predisposing factor.

2. AIMS OF THE STUDY

The general goal of this study was to describe scavenging behaviour of wildlife on wild boar carcasses in Hiiumaa.

Specific aims were

- to find out, which animal species are in contact with or scavenge wild boar carcasses
- to investigate if intraspecies scavenging occurs among wild boar in Hiiumaa.

3. MATERIALS AND METHODS

3.1. Experimental setting

A field experiment was conducted using hunted wild boar carcasses and camera traps to register behaviour of animals on wild boar carcasses.

3.2. Ethics statement

The wild boar carcasses were purchased from the local hunter and the wild boars were hunted in the process of normal hunting activity. No animals were killed for the purpose of this study. Animals filmed by cameras were not disturbed nor harmed during the study.

3.3. Carcasses

Four different carcasses and one gut pile were used and put in place during the time of filming and characteristics of each carcass were written down (Table 3.).

Table 3. *Characteristic of carcasses used in the study and their persistence*

	Sex	Age (years)	Weight (kg)	Date of placing	Date of only bones and skin left	Persistence of carcass in days	Remarks
Carcass 1	female	2+	90	21.11.2016	26.12.2016	35	
Carcass 2	male	4	70	11.1.2017	29.1.2017	18	
Carcass 3	male	4-5	100	13.2.2017	27.3.2017	42	
Carcass 4	male	2+	60	6.8.2017	14.8.2017	8	Head removed; gut pile placed aside

3.4. Location

The investigation was performed in a forest located in Hiiumaa, Emmaste municipality, Metsalauka village. Hiiumaa is a second largest island in Estonia and is located in the Baltic Sea 22 km from the mainland. The latitude of the location is 58.72, and the longitude is 22.57.

Hiiumaa was selected as the location because during the time of study, no cases of ASF were detected in Hiiumaa. Secondly, there is a legal obligation to remove wild boar carcasses from the forest in areas, where ASF has been found in Estonia. In addition, as ASF is often lethal disease, especially when first introduced, there wouldn't be that many wild boars to study, in areas where ASF is spread.

3.5. Cameras

Camera traps were used to observe wild boar carcasses. The material for the study was collected from 21.11-2016-18.10.2017 (332 days). Two cameras were set to film the carcasses simultaneously from different directions. The cameras were installed on trees at a distance of 5 m to the carcass and a height of 1.5 m above the ground. The camera type was Uovision UM-595-2G; infrared heat and motion-sensitive digital camera. The cameras were programmed to take a series of three photos if activated with one-minute pause to the next activation.

One of the cameras stopped working couple of times, and it didn't film during following periods 26.11.2016-13.12.2016, 25.1.2017-14.4.2017 and 8.6.2017-25.7.2017. In total, 16 967 pictures from two cameras were collected and analysed.

3.6. Data collection and handling

Data from the pictures was collected to a Microsoft Office Excel spreadsheet. Every event was placed on a separate row and one event was considered as a detection of a certain species, therefore species detected simultaneously were placed on separate rows. Based on the information in pictures, 10 different variables were collected and exported to a spreadsheet. In addition, possible cannibalistic behaviour (such as tearing, removing, chewing or breaking down soft tissue and bones) of wild boar was estimated visually from the pictures.

These variables were:

- DATE – date of the event
- TIME_FIRST SEEN – beginning of the event, when the animal/animals was first seen on camera
- TIME_LAST_SEEN – end of the event when the animal/animals was last seen on camera
- SPECIES – animal species seen
- N_INDIVIDUALS – how many individuals of the same species seen
- CAMERA_ID – whether seen in only one of the cameras or both
- AIR_TEMP_C – air temperature in degrees Celsius
- CONTACT DETECTED – whether there was a contact with the carcass or not
- N_INDIVIDUALS IN CONTACT – how many individuals of the same species in contact with the carcass
- REMARKS

3.7. Statistical analysis

Data was described by using descriptive statistics in Microsoft Office Excel. Graphs and tables were developed to visualize the results.

4. RESULTS

4.1. All species detected and species in contact

In total, 17 vertebrate species were detected in cameras (Table 4.). All detected species belonged to either avians or mammals. In addition, unidentified species were divided into two groups: unidentified mammal and unidentified avian. In total 8674 animals were seen. 79,69% of animals identified were avians and 21,86% were mammals. Common raven was most frequently identified (n=3232) followed by raccoon dog (n=369), wild boar (n=274) and red fox (=186).

11 species were noticed having a contact with wild boar carcass (Table 5.). These species were common buzzard (*Buteo buteo)*, common raven (*Corvus corax)*, Eurasian magpie (*Pica pica)*, European pine marten, golden eagle, grey wolf, hooded crow (*Corvus cornix)*, raccoon dog, red fox, white-tailed eagle (*Haliaeetus albicilla)* and wild boar. Common raven was most common species in contact with 74,73% of all individuals in contact followed by raccoon dog and wild boar, 9,95% and 4,50%, respectively.

Table 4. *Species detected in the cameras in English, Latin and Estonian*

English	Latin	Estonian
Common buzzard	*Buteo buteo*	Hiireviu
Common crane	*Grus grus*	Sookurg
Common raven	*Corvus corax*	Ronk
Domestic cat	*Felis catus*	Kass
Eurasian brown bear	*Ursus arctos arctos*	Euroopa pruunkaru
Eurasian magpie	*Pica pica*	Harakas
European elk	*Alces alces*	Põder
European pine marten	*Martes martes*	Metsnugis
European roe deer	*Capreolus capreolus*	Metskits
Golden eagle	*Aquila chrysaetos*	Kaljukotkas
Grey wolf	*Canis lupus*	Hunt
Raccoon dog	*Nyctereutes procyonoides*	Kährik
Red deer	*Cervus elaphus*	Punahirv
Red fox	*Vulpes vulpes*	Rebane
White-tailed eagle	*Haliaeetus albicilla*	Merikotkas
Wild boar	*Sus scrofa*	Metssiga

Table 5. *Total number and percentage of individuals in contact by species*

Species	Total number of individuals in contact	Percentage of all individuals in contact
Common raven	1742	74,73 %
Raccoon dog	232	9,95 %
Wild boar	105	4,50 %
Red fox	97	4,16 %
Common buzzard	64	2,75 %
White-tailed eagle	34	1,46 %
Hooded crow	22	0,94 %
Grey wolf	15	0,64 %
Eurasian magpie	8	0,34 %
Golden eagle	6	0,26 %
European pine marten	5	0,21 %
Unidentified mammal	1	0,04 %
Total	2331	100%

38,32% of wild boars were in contact with the carcass (Figure 1.) 77,27% of white-tailed eagles were in contact with the carcass, which was the highest followed by golden eagle (75,00%). From identified species in contact, hooded crow was the most sparsely in contact, 32,84% of them. Species in contact apart from wild boar and Eurasian magpie were detected scavenging on carcass, but magpie and was considered as a possible scavenger.

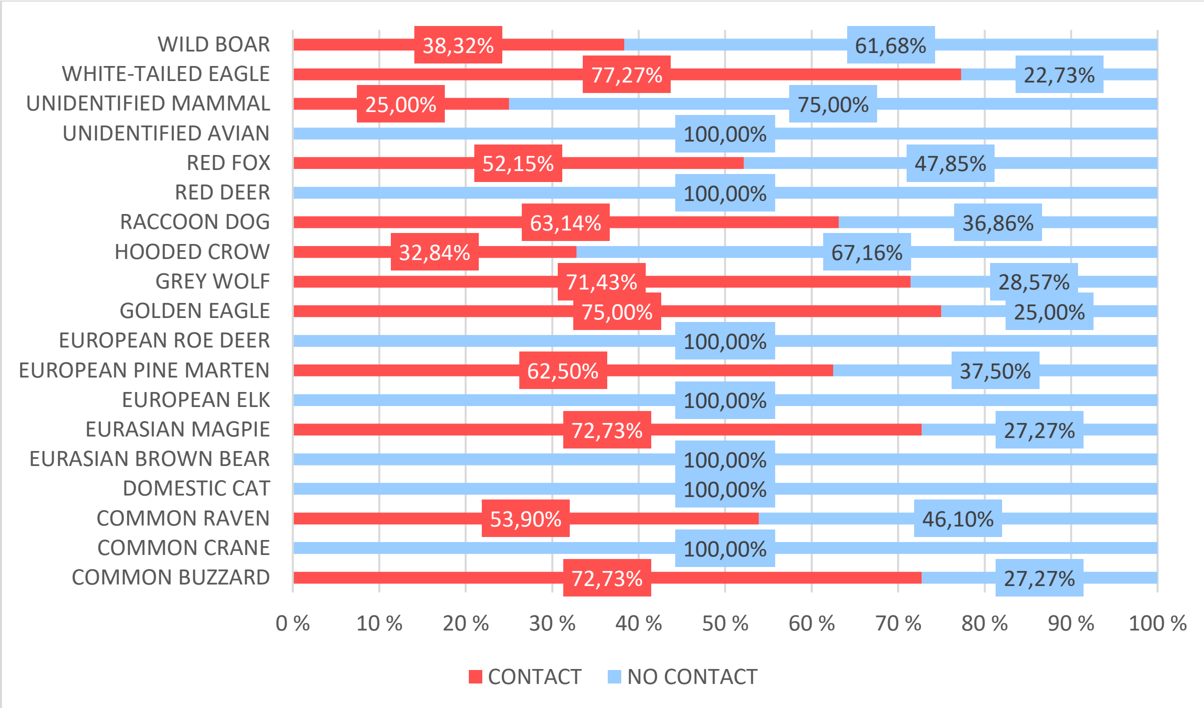

Figure 1. *Percentage of animals in contact and not in contact by species*

4.2.Persistence of carcass and its relation to contacts

Time from when the carcass was placed until there were only bones and skin left was calculated. Third carcass lasted longest, 42 days and it was placed in February. Fourth carcass was placed in August and it lasted for shortest period of time, 8 days.

Number of animals and animals in contact per week during the time from placing the carcass until only skin and bones left were observed on every carcass (Figures 2., 3., 4., and 5.). Peak in both, number of all animals detected and animals in contact occurred one week or less before when there was only bones and skin left from carcass.

Figure 2. *Number of individuals from week the first carcass placed until the second carcass placed. The vertical lines represent the time from when carcass was placed until only bones and skin left*

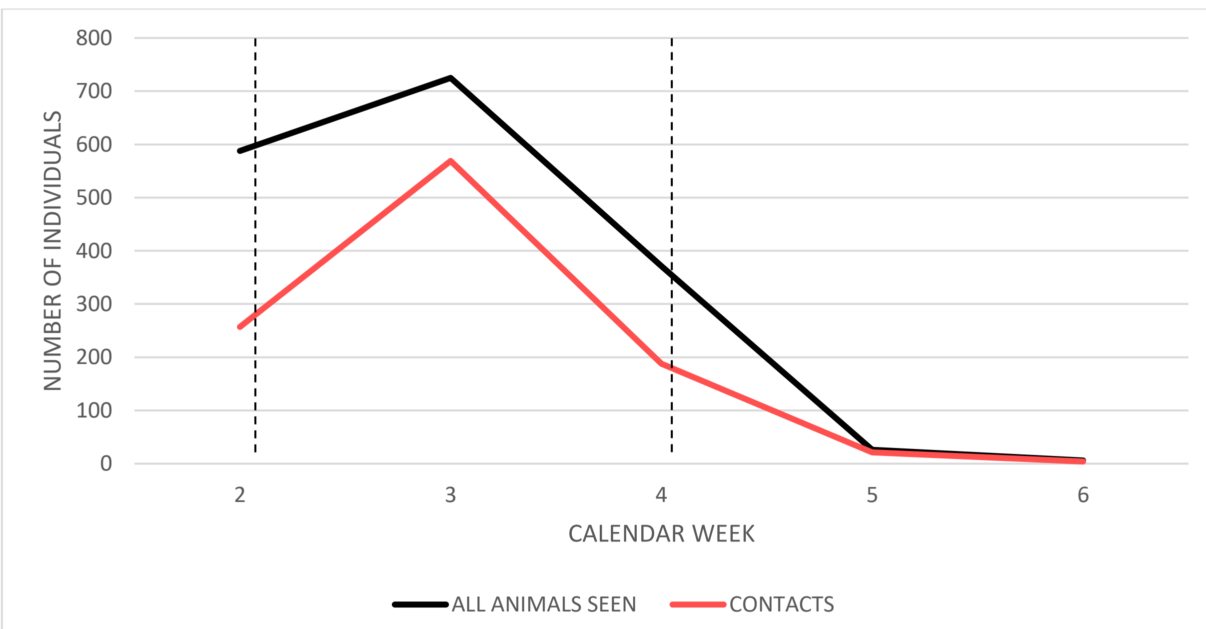

Figure 3. *Number of individuals from week the second carcass placed until the third carcass placed. The vertical lines represent the time from when carcass was placed until only bones and skin left*

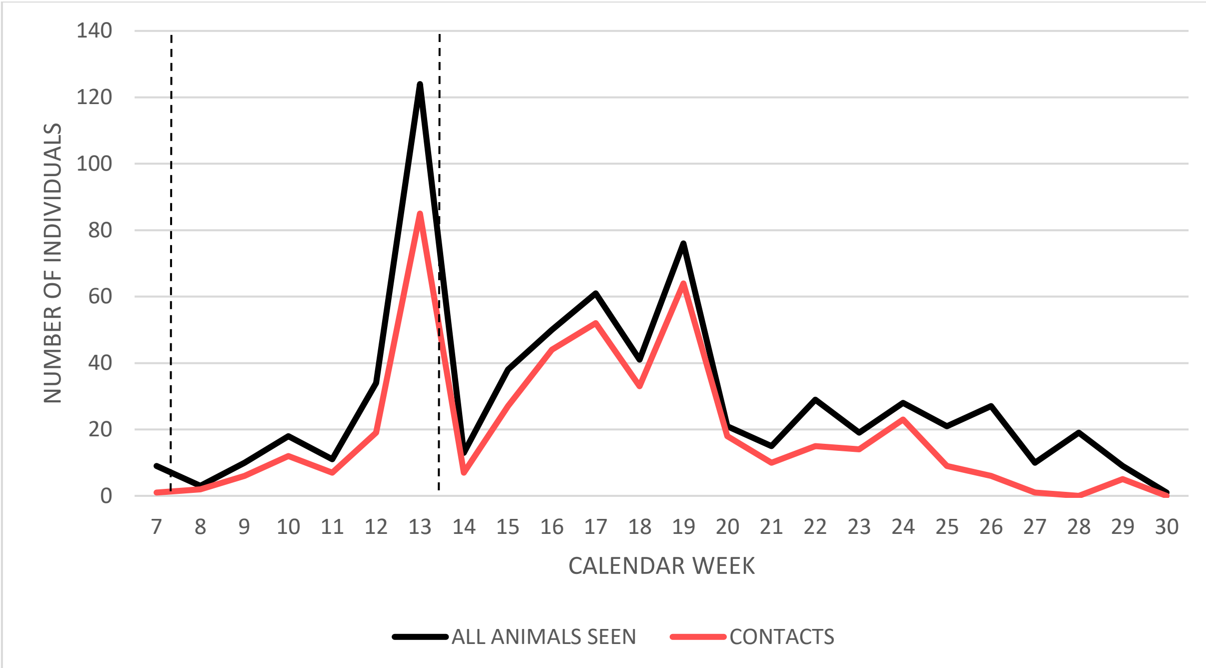

Figure 4. *Number of individuals from week the third carcass placed until the fourth carcass placed. The vertical lines represent the time from when carcass was placed until only bones and skin left*

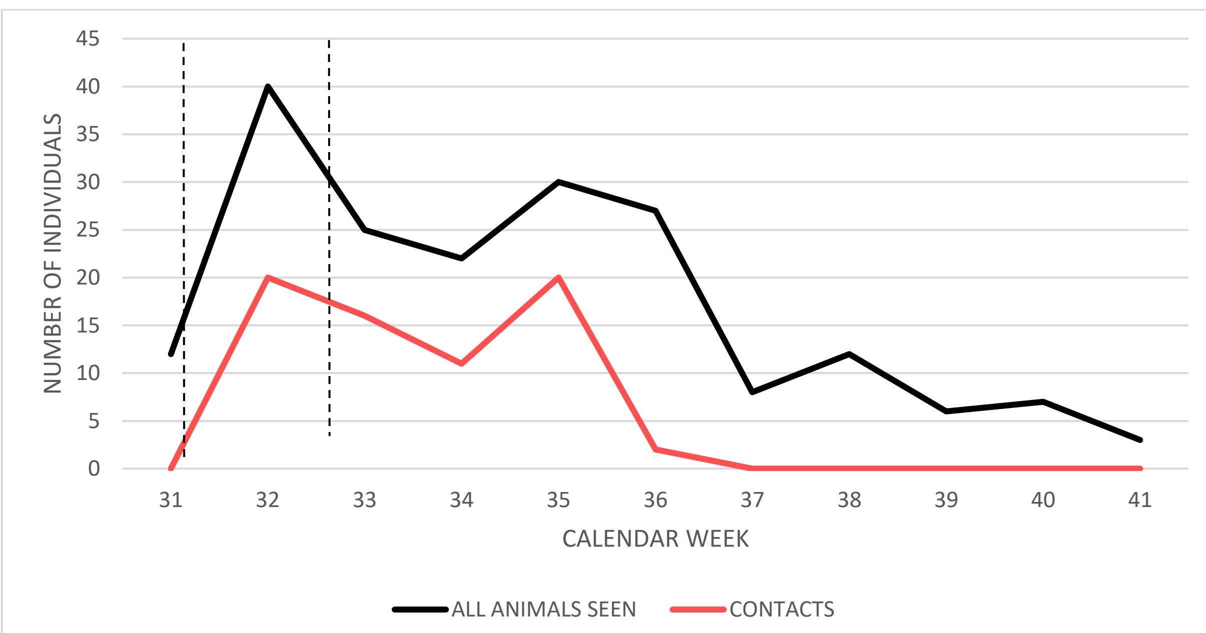

Figure 5. *Number of individuals from week the fourth carcass placed until the end of filming. The vertical lines represent the time from when carcass was placed until only bones and skin left*

4.3. Species detected according to the time of the day

Day was divided into two variables "Day" and "Night". "Day" is considered as a time from 8am until 8pm and "Night" from 8pm until 8am. Percentage of events by species between day and night was calculated (Figure 6.). Wild boar, red fox, raccoon dog events occurred more often during the night, 73,33%, 65,17% and 57,89%, respectively. Almost all avian species were detected only during the day, nonetheless unidentified avian, common raven, and common buzzard events were detected also during the night, 33,3%, 1,90% and 1,16% respectively.

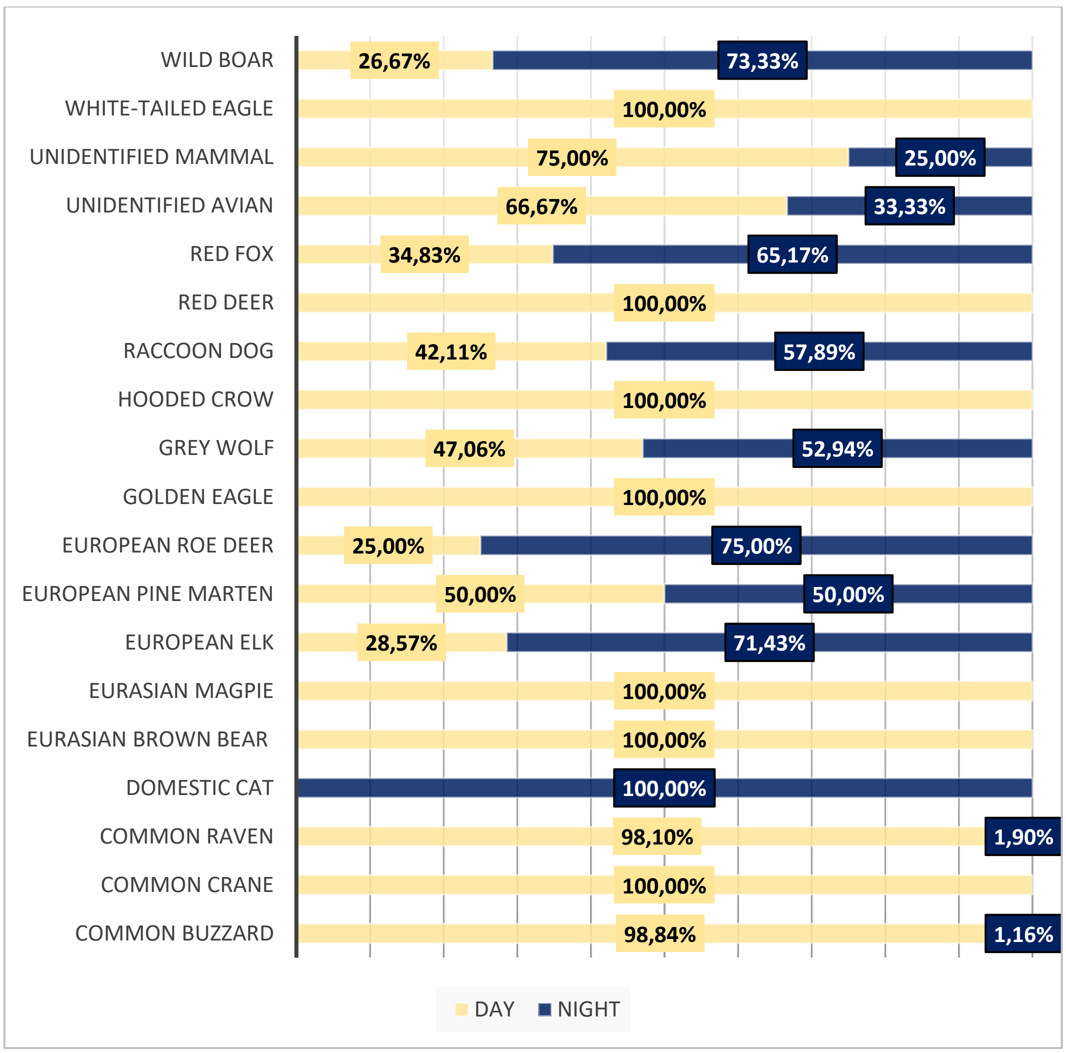

Figure 6. *Percentage of events during the day and night per species*

4.4. Observations of wild boar

In total, 274 wild boars were detected on cameras, out of which 38,32% were noted having a contact with the carcass (Figure 7.). Possible cannibalistic behaviour of wild boar was estimated and there were no signs of intraspecies scavenging of wild boar.

Wild boars were seen throughout the year. The highest number of wild boars per month occurred in September, 37 (Figure 7.). Lowest number per month occurred in November (2). The highest number of contacts were in June and April, 22 and 21, respectively. There weren't any contacts detected in autumn (from September until November).

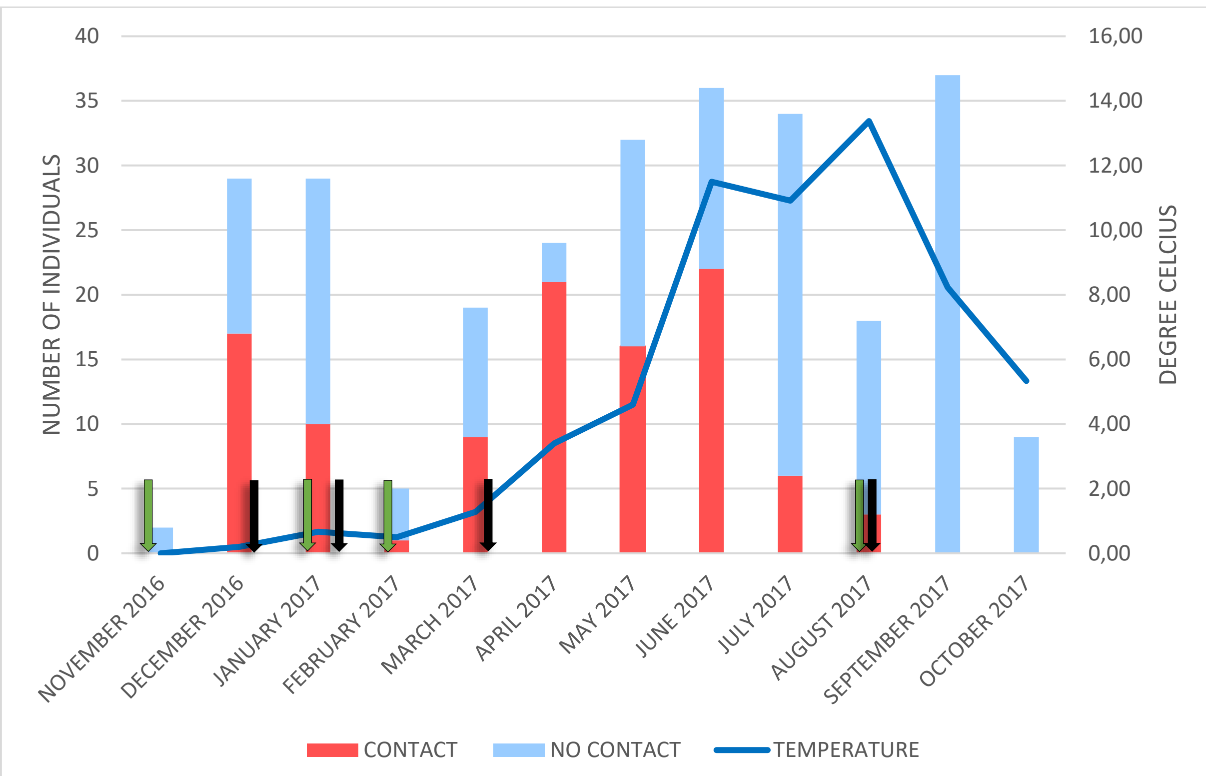

Figure 7. *Number of wild boars detected in contact and not in contact and average temperature of wild boar events on monthly basis. Green arrows represent when new carcasses were placed and black arrows when only bones and skin were left*

4.5. Observations of avians

Most avian contacts occurred during January and December (Figure 8.). Number of contacts by avian species were divided into two separate charts (Figures 9. and 10.) due to significant difference in number of contacts, as common raven had drastically more contacts compared to other species. Common raven was most common avian species detected, in total there were 1742 contacts detected (Figure 9.). Most contacts were detected in January and December and less than 100 contacts were detected during other months. Common buzzard was second common avian species detected in contact after common raven (Figure 10.) and was seen mostly in January and December, but also some individuals were detected from February until March. Hooded crow was detected only in January. Most white-tailed eagles in contact were observed in December.

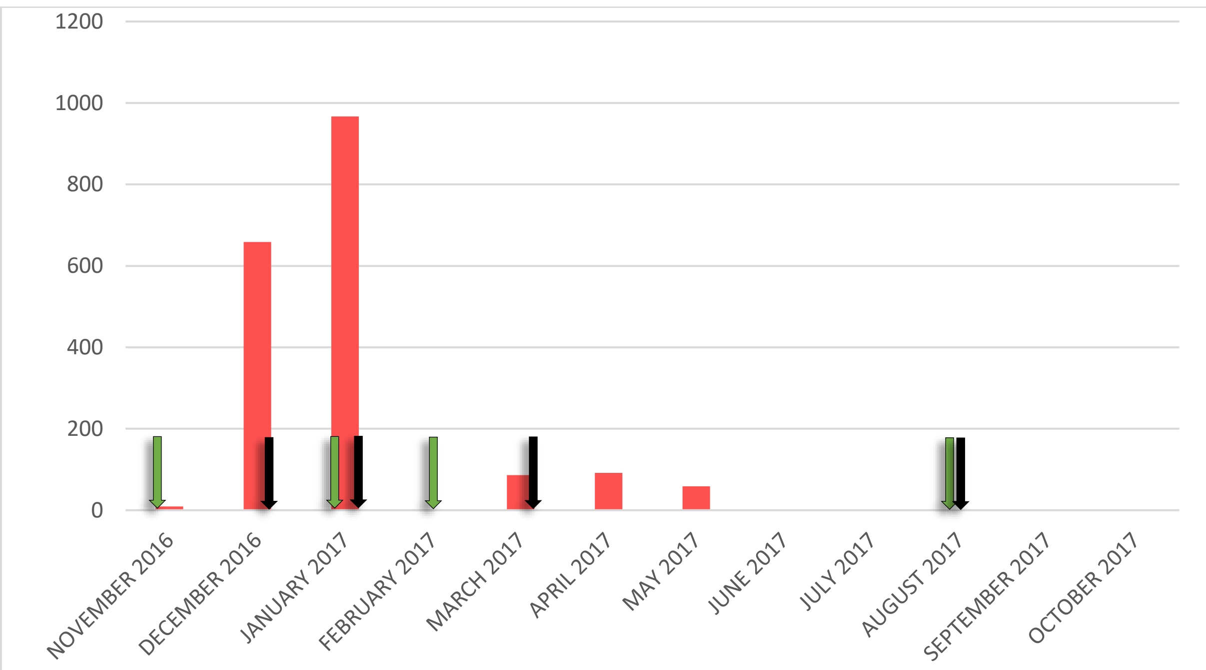

Figure 8. *Number of avian contacts on monthly basis. Green arrows represent when new carcasses were placed and black arrows when only bones and skin were left*

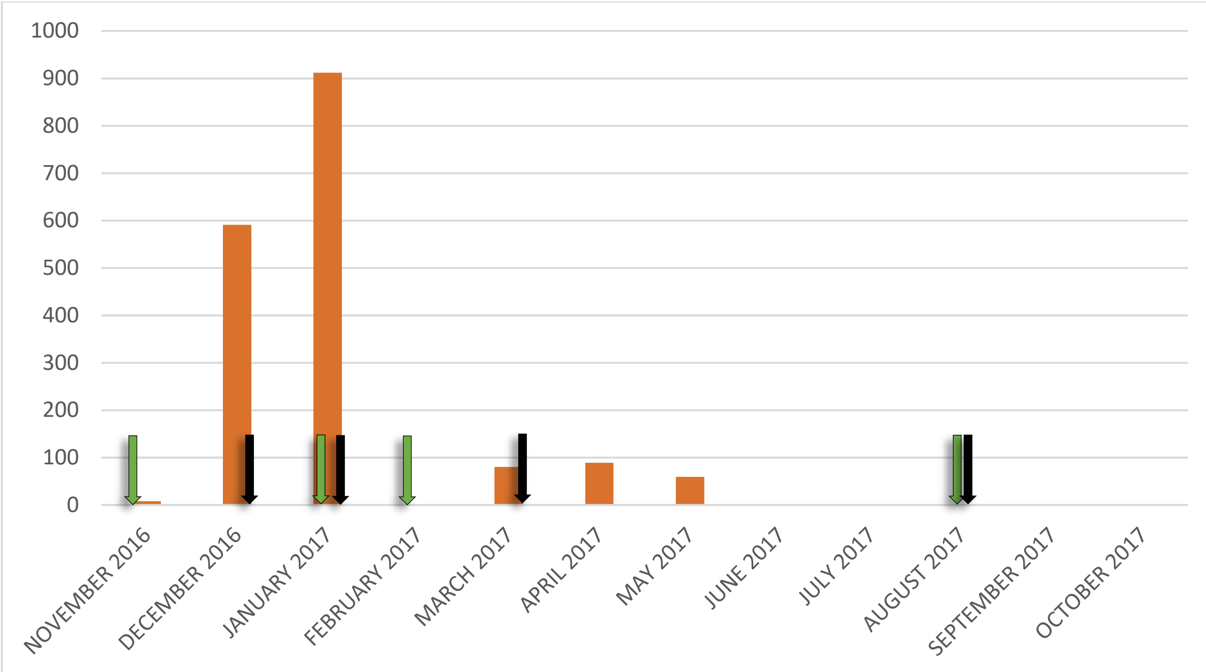

Figure 9. *Number of common ravens in contact on monthly basis. Green arrows represent when new carcasses were placed and black arrows when only bones and skin were left*

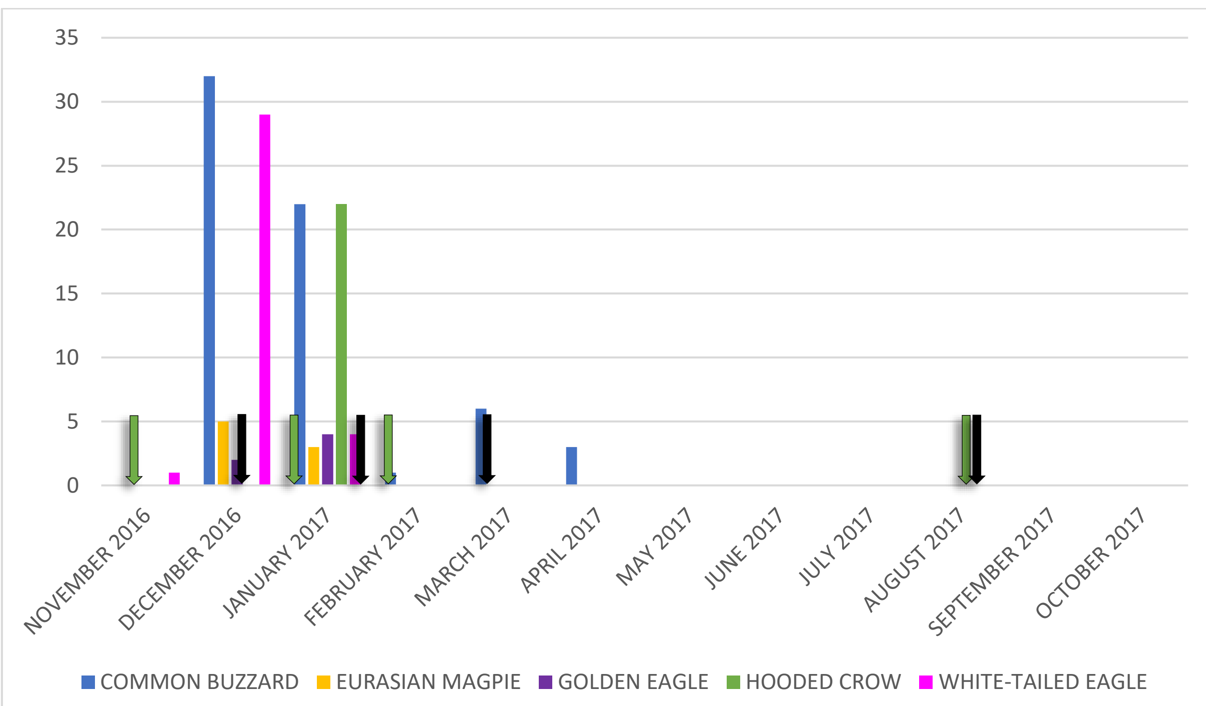

Figure 10. *Number of avian contacts (common raven excluded) on monthly basis***.** *Green arrows represent when new carcasses were placed and black arrows when only bones and skin were left*

4.6. Observations of raccoon dog and red fox

In total, 233 raccoon dogs and 97 red foxes were seen in contact during the study period. Raccoon dog was seen in contact 1,40 times more often than red fox. 63,14% of raccoon dogs detected were in contact with the carcass and 52,15% of red foxes (Figure 11.).

There was fluctuation in number of animals detected between months in both species (Figure 11.). Highest number of contacts by raccoon dog occurred in December, whereas in red fox in January. There were no contacts by raccoon dog detected in September and October. There were no contacts in July, October and November by red fox.

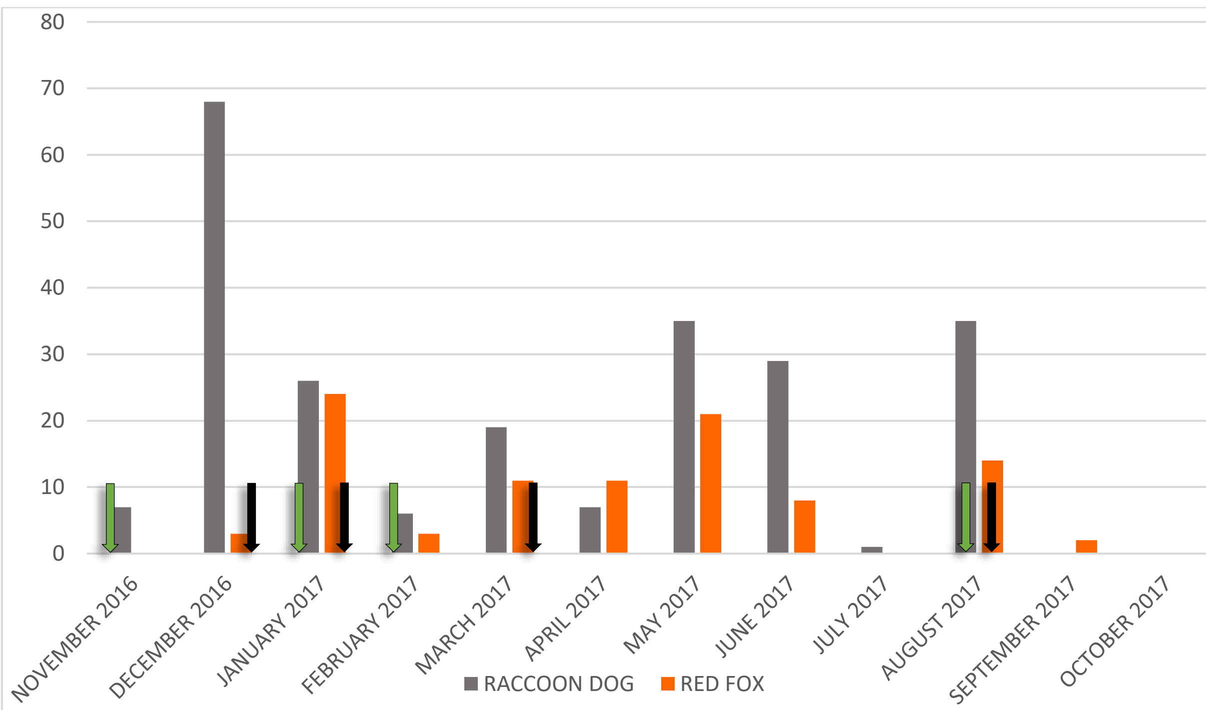

Figure 11. *Number raccoon dogs and red foxes in contact per month. Green arrows represent when new carcasses were placed and black arrows when only bones and skin were left*

5. DISCUSSION

Altogether, 12 vertebrate species were identified, out of which 7 were avians and were 10 mammals in our study. Species are similar compared to previous studies in Poland and Germany (Probst *et al.*, 2019; Selva *et al.*, 2005). Selva *et al.* (2015) found 36 species, including 22 avians and 14 mammals, including wild boar during their study in Poland. Larger number of species is likely due to several factors. The number of carcasses was significantly higher (over 200) and carcasses were from several different species, including ungulates, carnivores, and smaller herbivores. Besides, the study period was significantly longer, over 5 years. Probst *et al.* (2019) detected 22 vertebrate species, which included 13 mammals and 9 birds in their study conducted in Germany, thus the number of species is more similar. Furthermore, study design in Germany was more similar to ours. Lastly, other reasons for alterations in species are possibly related to differences in territory, climate, and biological community.

Common raven was both most frequently identified and in contact with the carcass in our study followed by three mammalian species: raccoon dog, wild boar, and red fox. Due to high number of common ravens, birds were seen more often than mammals. Probst *et al.* (2019) had the opposite result: mammals were more often visiting the carcass. The difference seems to be largely because high number of ravens. Apart from high number of common ravens, results were fairly consistent. Commonly ravens were around the carcass in large groups (up to 20 individuals seen simultaneously) and distinction between the events was in some cases difficult when number of individuals was constantly changing between pictures. It is a possibility, that the number of ravens was somewhat over estimated.

Common raven, raccoon dog, red fox, common buzzard, white-tailed eagle, hooded crow, grey wolf and golden eagle were identified as scavengers in this study, and Eurasian magpie was recognised as possible scavenger. These species, including Eurasian magpie has been recognized scavenging in other studies as well (Gomo *et al.*, 2020; Moleón *et al.*, 2017; Selva *et al.*, 2005; Young *et al.*, 2015, 2014).

The carcass lasted longer during the cold season than in summertime, which is similar to study performed in Germany (Probst *et al.*, 2019). Decreased decomposition rate of the carcass in winter time has been suggested being a possible cause for longer persistence (Young *et al.*, 2014). In addition other variables such as atmospheric conditions, type of habitat, type of surroundings, scavengers, size of the carcass and integrity of the skin affect how long the carcass will last in the environment (Probst *et al.*, 2019). Besides, the carcass might be frozen and therefore it requires more effort and time to consume (Selva *et al.*, 2005). Moreover, shorter persistence of carcass in summer could be due to increase in activity of invertebrate scavengers and microbes (DeVault *et al.*, 2003). Even though persistence of carcasses was longer in winter, there were noticeably more contacts simultaneously. Increase in scavenging activity during winter was also observed by Selva *et al.* (2005). On the other hand, Probst *et al.* (2019) noted in their study that carcasses exposed in colder season were visited less often. Because birds were visiting carcass more frequently than mammals during winter in our study, one explanation could be that birds are not as effective consuming carcass because beak is not as effective in tearing the skin and muscles apart and gaining access to internal organs compared to carnivore mammals with sharp teeth.

Peak in both, all animals detected and animals in contact with the carcass took place closely before skeletonization. The result is different compared to Probst *et al.* (2017), where most of the visits occurred during the first two weeks after the exposure. Also, Young *et al.* (2014) noted that scavenging on deer carcasses was most frequent when the carcass was still fresh. One possible explanation could be that 3 out of 4 carcasses were placed during cold season, when the decomposition of carcass takes longer, thus the carcass remains fresh for longer.

Mammals were detected more often during the night whereas birds were almost exclusively detected during the day. The result is consistent with the study performed by Probst *et al.* (2017). This seems reasonable as avian species detected are diurnal and active during the day whereas wild boar, raccoon dog and red fox are considered as nocturnal (active during the night).

38,32% of wild boars were in contact with the carcass, which is lower than in previous study conducted in Czech Republic, 81% (Cukor *et al.*, 2020a). Even though wild boar was identified having a contact with the carcass, there were no signs of intraspecies scavenging. Same result was received by Probst *et al.* (2019) in Germany. In turn, cannibalistic behaviour of wild boar has been described in Czech Republic and Poland (Cukor *et al.*, 2020a; Merta *et al.*, 2014). Both of these studies took place during the cold season and shortage in protein could be an underlying cause for intraspecies scavenging.

Common raven was identified most often, however most of the contacts were in winter, in December and January. The same pattern occurred in similarly other avian species. Some contacts were detected in springtime by common raven and common buzzard. Probst *et al.* (2019) had noticed the similar pattern that birds visit carcass more often in colder season. Possible cause for this kind of behaviour could be that during the warmer season, there is a wider selection of feeding opportunities for birds.

Over 50% of both reed foxes and raccoons were in contact with the carcass. Both were seen almost throughout the year, but less in autumn. This could be because there wasn’t any carcass available for most of the time in autumn. Red foxes have been observed scavenging in all stages of decomposition of the deer carcass, but preferring when carcass is fresh, at an early stage of decomposition or when skeletonized (Young *et al.*, 2015). Probst *et al.* (2019) noted red foxes and raccoon dogs scavenging on carcasses both warm and cold season and at different stages of decomposition of carcass.

There are differences between our study design and in other studies analysed in this discussion. Our study period was approximately one year, which was similar to study by Probst *et al*. (2019) in Germany, whereas in Cukor *et al*. (2020a) study period was only half a year from January until June. Two studies in Poland had the longest and shortest study periods. In Merta *et al*. (2014) study period was 4 months in cold season from October until January and in Selva et *al*. (2005) it was 3,5 years. We used camera traps to record animals visiting on carcasses similarly to studies in Czech Republic and Germany (Cukor *et al*., 2020a; Probst *et al.*, 2019). Merta *et al*. (2014) examined stomach contents of hunted wild boars to find out their diet during autumn-winter. Selva *et al*. (2005) examined carcasses by frequent visits and used direct observations such as tracks in the snow, feces and feathers to identify species scavenging on carcasses.

One limitation in our study was low number of carcasses. Availability of carcasses was not uniform throughout the year and there were gaps when there weren't carcasses available especially during summer and autumn. In addition, there was only one location for the carcasses used. Finally, our carcasses were quite similar (adults up to 100kg). In other studies, there were several types of carcasses used, including different ages from piglets to adults and from both sexes in several locations Probst *et al*. (2019) studied 32 carcasses on 9 different locations around one town. Cukor *et al*. (2020a) had 7 carcasses and each were placed on different hunting districts. Highest number of carcasses were in studies in Poland conducted by Merta *et al*. (2014) and Selva *et al*. (2005), 83 and 42 respectively. Probst *et al*. (2019) had noticed, that carcass type has an influence on the number of visits.

6. CONCLUSIONS

Based on our results, there are 11 species that are in contact with wild boar carcasses in Estonia, 6 of them were avians and 5 were mammals. All these species apart from wild boar were noticed scavenging and additionally, these species are known for their scavenging behaviour.

Birds were active mainly during the day, and mammals during the night and to some extent also in daytime. Avians were scavenging mostly on winter whereas mammals were scavenging throughout the year.

Almost 40% of wild boars were noticed having a contact with the wild boar carcass, but no clear signs of intraspecies scavenging were identified. Wild boar visits occurred more frequent during the night. There were fluctuations in number of wild boar visits between calendar months, and two peaks in visits were in early summer and in beginning of autumn.

7. RECOMMENDATIONS

Because direct contact has been found out as a way of disease transmission in case of ASF and therefore, in aiming to prevent transmission, carcasses of dead wild boars should be removed from the environment.

Further studies are required to describe scavenging behaviour in other parts of Estonia with a higher number of different types of carcasses to find out if there are differences in scavenging behaviour for example between mainland and largest islands (Saaremaa and Hiiumaa) or in habitat of carcass location (like forest vs. open area).

Scavengers could possibly spread diseases through several ways such as being as maintenance hosts, through feces and acting as mechanical vectors. Therefore, further studies are required to investigate, if scavengers can participate in disease transmission via these routes.

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