DYNAMICS OF WOLF PREDATION ON LIVESTOCK IN CROATIA

Koutis, Irisz

THE UNIVERSITY OF ZAGREB
FACULTY OF VETERINARY MEDICINE

Irisz Koutis

DYNAMICS OF WOLF PREDATION ON LIVESTOCK IN CROATIA

Master's Thesis
Zagreb, 2023

University of Zagreb

Faculty of Veterinary Medicine

Veterinary Biology Unit

Head: prof. dr. sc Maja Popović

Mentor: prof. dr. sc. Josip Kusak

University of Zagreb

Faculty of Veterinary Medicine

Forensic and Judicial Veterinary Medicine Unit

Head: prof. dr. sc. Severin Krešimir

Mentor: prof. dr. sc. Severin Krešimir

Members of the Committee for the defence of Diploma thesis:

1. Prof. dr. sc. Alen Slavica
2. Prof. dr. sc. Josip Kusak
3. Prof. dr. sc. Krešimir Severin
4. Assoc. prof. dr. sc. Magda Sindičić

ACKNOWLEDGEMENTS

I would like to thank my mentors, prof. Josip Kusak and prof. Krešimir Severin, for their continued support and patience throughout the process of writing my master thesis.

TABLES:

Table 1.: The average numbers of domestic animals killed, wounded and killed or wounded, per case of depredation

Table 2: Chi-square comparation among regions, using the availability (density, n/km^2) of livestock and intensity of wolf damage (n/km^2) per species of livestock. In all testing pairs the degree of freedom was 1 and significance threshold was at 0.05.

Table 3: Prevention measures implemented per county and the number of cases of depredations, minimum and maximum heads of livestock killed per attack and average number of livestock killed per attacks.

Table 4.: The preventive measures implemented by farmers and the number of depredation cases by category of measures implemented, partially implemented, or not implemented for prevention.

Table 5.: Degree of prevention measures implemented by counties affected by depredation.

Table 6.: Number of attacks per domestic animal species regarding degree of implemented prevention measures.

FIGURES:

Figure 1.: Number of reported livestock depredation cases per species of large carnivores identified as the perpetrator in the period of 2010-2020

Figure 2.: Number of reported livestock depredation cases by wolves per county in the period of 2010-2020

Figure 3.: Number of reported livestock depredation cases by wolves per month of occurrence in the period of 2010-2020

Figure 4.: Number of reported livestock depredation cases by wolves per time of day of occurrence in the period of 2010-2020

Figure 5.: Number of reported livestock depredation cases by wolves per species of livestock attacked in the period of 2010-2020

Figure 6.: Number of reported livestock depredation cases by wolves per location of livestock attacked in the period of 2010-2020

TABLE OF CONTENTS

1. Introduction 1
1.1 Wolf biology 1
1.2 Description of predation of wolves 1
1.3 The population status and legal status of wolves in Croatia 2
1.4 Goals 3
2. Literature Review 4
2.1 Human-wildlife conflict created by wolf predation 4
2.2 Methods applied in other countries for the mitigation of the damage caused by wolves 5
3. Materials and methods 8
3.1 Reliability of data 8
3.2 Study Area 8
3.3 Statistical Analysis 8
4. Results 10
4.1 Livestock damage cases by the predator species 10
4.2 Wolf attacks by counties and regions 11
4.3 Seasonal and diurnal patterns of wolf attacks on livestock 12
4.4 Wolf attacks by species of domestic animals 13
4.5 Wolf attacks by location 14
4.6 The ratio of wounded to killed livestock in wolf depredation cases 15
4.7 Comparation of livestock density and the numbers of wolf attacks 16
4.8 The comparation of the species of livestock attacked with the degree of protection measures implemented. 16
5. Discussion 20
6. Conclusion 23
7. Bibliography 24
8. Abstract 28
9. Sažetak 28
10. Curriculum Vitae 29

1. Introduction

1.1 Wolf biology

The grey wolf is the largest member of the *Canidae* family, with seven recognized Eurasian and five North American subspecies. Their body size differs somewhat based on the geographical area (SILLERO-ZUBIRI et al., 2004). The grey wolf in Croatia shows sexual dimorphism, with the males being larger from about six months of age. When fully grown, both genders together measure an average of 70 cm at the shoulder and have a length from the tip of their nose to that of their tail of about 170 cm. The females measure an average of 29 kg, while the males can measure an average of 39 kg (PLATIŠA et al., 2011). They have thick fur, the colours of which can vary in mixtures between white, black, grey and brown (HEPTNER et al., 1998). The individuals living in Croatia are mostly grey, darker on the dorsal section and progressively lighter on the ventral sections, including the tail, abdomen, neck, and the legs. Most of wolves have a dark stripe on the front sides of forelegs (KUSAK et al., 2018). Their maximal lifespan in the wild is around 13 years while in captivity it can be up to 16 years (MECH, 1988).

1.2 Description of predation of wolves

Since prey naturally do not give up without a fight and wolves are not fierce enough to overpower and kill prey at will, wolves will always target weaker and more vulnerable prey to minimize the risk of injury (MECH et al., 2015). In the case of wild sheep as a prey, rams for instance will get bunched together into a tight group, with their horns facing outward and butting the wolves if they should come too close, while slowly moving toward an escape route as a group, waiting for the right moment to gallop (MECH et al., 2015). When such tactics on the part of the wild sheep prove successful in avoiding depredation, in a way that wolves back away, it indicates that the wolf can assess the situation and anticipate the injuries that the rams could potentially cause. As any of the hooved prey species of the wolf could prove lethal, it makes it highly improbable that a wolf would "kill for sport" (MECH et al., 2015). The only situation where a wolf may kill more than its immediate need, is if it finds a group of vulnerable prey, in which case they will instinctively kill more than they require (MECH et al., 2015). However, if scavengers do not finish these 'leftovers', wolves tend to return to feed on and finish the carcasses which were often regarded as surplus kill (MUISANI et al., 2010).

Wolves are territorial pack animals, and their range is known to decrease with a growing biomass of prey (JEDRZEJEWSKI et al., 2007). Within said territory, to maximise the likelihood of coming across vulnerable prey, they constantly alter the locations of their hunts (MECH et al. 2015). However, the range which they cover changes by season, covering a greater portion of their territory during winter and a much smaller range when they have pups in May-June (JEDRZEJEWSKI et al., 2007). For example, as observed about Denali wild sheep by Murie in Denali Park, Alaska in 1939;" *The habit of cruising far in its hunting gives the wolf opportunity to find weak sheep over a large range and to come on undisturbed sheep, some of which it might find in a vulnerable location."* As they circulate around these routes in their territory, they encounter prey in constantly changing conditions and give chase multiple times unsuccessfully, thus weeding out the most vulnerable individuals (MECH et al., 2015). As such they gain information about the vulnerability of different prey species and the parameters of the prey (species, age, sex, condition) is subjected to constant change (MECH and PETERSON, 2003). In the end, wolves are opportunistic eaters and will consume whatever they capture or any fruits (berries, melons) they may come across (PETERSON and CIUCCI, 2003). Generally, as they move through their territories, wolves use cover, both to avoid detection by prey, as well as by humans. Therefore, grazing livestock in forested areas increases the risk of depredation (MUISANI et al., 2010). Likewise, rugged terrain is shown to increase the likelihood of depredation on cattle by 2-9 times, compared to low prairie-like flat terrain (DORRANCE, 1982). An analysis of wolf scats (n=22) in Croatia, including scats from the southern edge of Velebit, up until the border with Montenegro, confirms this preference, as it showed residues of wild prey in 13.6 % and of farm animals in 86.4 % of the samples, but the attacks on livestock happened predominantly in areas of lower altitude towards the sea, even though the mountainous areas had a significant number of domestic sheep and goats (HUBER et al., 1999).

Regardless of the prey species the hunting technique of wolves is based on the exhaustion of prey and the singling out of a weaker individual during the chase and then overcoming the prey. Much like hyenas or African wild dogs, wolves must catch up to the prey, slow it and disable it to start feeding. This can be quite dangerous depending on the prey species, as a prolonged struggle increases the risk of injury and fatality for the wolf itself (MECH et al., 2015).

1.3 The population status and legal status of wolves in Croatia

From the beginning of the 20th century, the availability of adequate habitats that can sustain wolf populations has been gradually decreasing due to human impact (less forested areas, building of roads, quantity of available prey), as have their numbers, but since the 1990's, wolves have started to recover (CHAPRON et al., 2014).

Wolves are considered to have lived throughout Croatia, as in 1894 at least one wolf was killed in every county (HUBER et al., 1999). However, since then the continental lowlands in the north of Croatia, along with the islands of the Adriatic Sea and the area of Istria, excluding Ćićarija and Učka, were not inhabited by wolves at the beginning of 1990ies (ŠTRBENAC et al., 2005). However, by 2020, regular wolf presence is seen in areas of Gorski kotar, Lika and Dalmatia, including the areas of the Dinaric border in the north and the southern slopes of Velebit, in the Banovina and Žumberak area (KUSAK et al., 2019).

In 1995 the wolf became a permanently protected animal species in Croatia under the Rules on the protection of certain mammalian species (Mammalia) in Narodne Novine (NN; Official Gazette of the Republic of Croatia) No 31/95. This led to the need for a management plan, the first one of which was created in 1999 (HUBER et al., 1999) and later in 2005, 2010 and 2019 (ŠTRBENAC et al., 2005, 2010; KUSAK et al., 2019). Official regulations regarding wolves have come a long way in Croatia, from wolves being considered as pests to be exterminated (BOJOVIĆ and COLIĆ, 1973), thorough the ban of wolf poisoning in 1972, to the status of protected species in 1995 under the Nature Protection Act (OG 80/13) and the Ordinance on strictly protected species (OG 144/13). Since wolves are a protected species, which can still create economic losses due to predation on livestock, there is a compensation system in place (ŠTRBENAC et al., 2005). For the farmer to claim the money, he/she must report the attack, which will be checked by a trained official from the competent authority, who will collect proof and determine the credibility of the claim. It must also be proven that the attack was indeed perpetrated by a wolf and not by another large carnivore such as a dog, bear, jackal or even lynx (ŠTRBENAC et al., 2005). Although a good first step, compensation programmes should encourage the use of preventive measures through husbandry practices, otherwise it can become a form of subsidy, leading to a permanent state of conflict (BOITANI and CIUCCI, 2009; COZZA et al., 1996). We can see such an example in Scandinavian countries, where both Norway and Sweden experience similar issues with depredation of livestock by wolves. However, there is a difference in that depredation is heavily subsidized by the government in Norway, thus creating a serious conflict. On the other hand, Sweden does not have such subsidies and farmers must take matters into their own hands and protect their livestock through management methods (LIBERG et al., 2010).

1.4 Goals

The aim of this study was to analyse the data set on wolf depredation of livestock, compiled by the responsible ministry between 2005-2020. As there were some changes in the structure of data from the damage reports through the years, I decided to focus on the period of 2010-2020, as it had consistent information for the parameters I wished to analyse. This data set is deemed complete and reliable, since it is in the interest of the owner to report any damages suspected to be caused by wolves, due to the compensation given by the state and because trained damage inspectors assess every case to confirm that the damages were indeed done by a wolf.

The goals were:

1. to identify the areas of Croatia most affected by wolf predation
2. to reveal the possible seasonal and diurnal changes in patterns of predation
3. the comparison of the damages caused by wolves-dogs-lynx-bears
4. the comparison of the frequency of wolf attacks by the livestock species
5. to compare the ratio of wounded to killed livestock
6. to compare between density of livestock in given areas and the numbers of attacks seen in those areas
7. to compare the species of livestock attacked with the degree of protection measures
8. to compare the number of animals killed per attack with the degree of protection measures
9. to compare livestock guarding against predatory attacks by regions of Croatia

2. Literature Review

2.1 Human-wildlife conflict created by wolf predation

The existing overlap in wolf and human presence in many countries results in conflict stemming from a competition for resources (SILLERO-ZUBIRI et al., 2004). The mere presence of the wolf has caused major anxiety in people in affected areas of Scandinavia, mostly out of fear for children, which has had a major impact on their overall quality of life (LIBERG et al., 2010). In the USA people still fear wolves even though there have been no proven cases of attacks on humans for a century (SILLERO-ZUBIRI and SWITZER, 2004). Past cases where wolves have attacked people, have been due to a rabid animal in the ’furious’ phase of the disease, rather than a conscious attack. Rabid animals will attack people repeatedly in a short period before succumbing to their illness (LINNELL et al., 2002). As rabies has mostly been eradicated from many parts of the wolf's natural range, the occurrence of attacks has dropped significantly (SILLERO-ZUBIRI et al., 2004). In Croatia there have been no reports of a healthy wolf attacking humans in the post WW2 period, while older reports are dubious. One case from Croatia reports a farmer being bitten by a rabid wolf on April 13th, 1997 (KUSAK, 1997).

Today, one of the key issues related to wolves are the attacks on livestock and hunting dogs. Up to 86 % of wolf attacks on dogs in Scandinavia happen while the dog is on a hunt (BACKERYD, 2007). Regarding the attacks on hunting dogs in Finland, TIKKUNEN and KOJOLA (2019) did a study, which first assessed the movements of GPS-collared wolves, paying special attention to how much time they spend in different areas within their territory. They found that wolves spent about 8% within the border zones, which constitutes about 11% of their full territory. Forty-five percent of all attacks analysed (n= 11) happened within this zone, indicating that wolves reacted to the dogs as potential competitors/intruders, and thus with the intention of eliminating them, they attacked or killed these dogs (TIKKUNEN and KOJOLA, 2019). It is more alarming for communities when wolves attack and/or kill dogs near human residences, as has been the case in Finland and Slovenia, which have reported several cases (LIBERG et al., 2010; ADAMIČ et al., 2004).

Besides the attacks on hunting dogs, which are both expensive and have sentimental value, the conflict with hunters is also based on competition for wild prey in certain regions. Although wolves are known to target sick and infirm animals, which are poor trophies and are not targeted by hunters, there is still major pressure in many countries from the hunting lobby to decrease wolf numbers (SILLERO-ZUBIRI et al., 2004). In 1995 in Slovenia, the Hunters Association felt that the damage wolves inflicted on the local wildlife was so unbearable that they issued a petition, to be able to shoot an extra 5 wolves and 5 lynxes (ADAMIČ et al., 2004).

The natural predatory behaviour of wolves often leads to major economic impact when livestock become targeted (HUBER et al., 1999). Changes in the management of livestock practices in the developed world, free of wolves, has resulted in the increase of the size of herds, while herding and the use of guard dogs have become rare, thus increasing their vulnerability to depredation (SILLERO-ZUBIRI and SWITZER, 2004). Domestic animals are particularly vulnerable as due to selective breeding and protection, they exhibit often inadequate anti-predator behaviour (SILLERO-ZUBIRI and SWITZER, 2004). Another issue with livestock is that they compete with wild herbivores for the same resources, therefore, they can impact wild prey by reducing their numbers or distribution in the given area, both of which can impact the pattern of predation and thus increase the risk of livestock depredation (SILLERO-ZUBIRI and SWITZER, 2004). Such is the case of the traditional extensive keeping of semi-domesticated reindeer (*Rangifer tarandus*) by the Sámi people, who claim that wolves are not compatible with this practice (LIBERG et al., 2010). In Norway the free-ranging sheep keeping also creates a great conflict with wolves, even though losses are subsidized (LIBERG et al., 2010). Since wolves hunt in packs, compared to other large carnivores in Europe, they are the most efficient predator when it comes to numbers per attack, as they killed or injured an average of 5.1 sheep per attack (n = 188) in a study conducted in Slovenia, with a range of 1- 40, whereas bears and lynx are very rarely involved in mass killings (ADAMIČ et al., 2004). The most at risk are hobby sheep farmers and small-scale family farms, who can't afford to invest too much in management methods of prevention. On the other hand, those that keep sheep as their main source of income do invest in prevention methods and are therefore the least vulnerable (ADAMIČ et al., 2004).

Livestock husbandry and guarding methods can make a significant difference, but several parameters can affect the likelihood of wolf attacks. Overlap in wolf territories and livestock grazing areas, as well as greater numbers of both within the same area increases the risk of depredation. Farms that have already had cases of wolf attacks are also more likely to have them in the future (DECESARE et al., 2018). Certain practices have also been found to increase the likelihood of depredation such as keeping yearling cattle herds, wolf culling, guarding livestock more intensely in autumn, whereas farms that guarded more in the winter and spring were less likely to be depredated (MUHLY et al., 2010). Seasonality has been proven both in European and North American study areas, showing that wolf depredation peaks in the late summer. The topography and vegetation also influence the chances of depredation as we see that in the USA most attacks occur in western Montana, which has a forest covered mountainous landscape separated by large valleys with grasslands or agricultural areas (DECESARE et al., 2018).

2.2 Methods applied in other countries for the mitigation of the damage caused by wolves

In Slovenia, when the law for the protection of wolves came into effect in 1993 and wolves began to resettle their historic range, the conflicts with livestock owners were rekindled. Due to the wolf's long absence from the region, the knowledge on management methods for the prevention of depredation and wolf ecology in general, was poor and a lot of negative feelings arose again in relation to the wolf (ADAMIČ et al., 2004). Similarly, in France, the new population, originating from the naturally expanded Apennine population of wolves, lead to a lot of conflicts and the payment of large sums for depredation compensations to livestock owners, who had forgotten the traditions of keeping animals in wolf occupied territories (ESPUNO et al., 2004). Today, one of the most common government responses to the human-wildlife conflict related to wolves is the payment of a compensation for the damages. In

Norway for instance, the government paid an average of €202,000 annually between 1999±2006, just for the losses of sheep (995/year) to wolf predation (LIBERG et al., 2010). Similar compensation systems are in place in the United States as well, for instance in Alberta, losses of cattle, sheep, goats, pigs and bison depredation are all covered by the government compensation system (MUHLY et al., 2010). Compensation schemes are a widespread method to alleviate the losses of farmers and attempt to relax opposition to canid conservation, however, they do nothing to alleviate the problem itself. Most of the time they don't identify issues or improve the situation, they do not encourage the implementation of management methods, but maintain a constant state of conflict (SILLERO-ZUBIRI et al., 2004). The Defenders of Wildlife in the USA have come up with a novel programme, the Proactive Carnivore Conservation Fund. Through it they share the cost with ranchers to install management methods to prevent depredation in the first place (SILLERO-ZUBIRI and SWITZER, 2004). Examples of non-lethal anti depredation methods include, but are not limited to electric fences, fladry, which is the use of flags tied to ropes around the perimeter of the area, disruptive stimuli, which can be activated when the collard wolf passes through the sensors at the perimeter of a farm or using shock collars in the first place. Another old management method is the use of trained guardian dogs, however, in some countries using donkeys or llamas with flocks of sheep has proven equally effective, while it takes less time to train these animals than dogs (SILLERO-ZUBIRI and SWITZER, 2004).

Other programmes have tried to alleviate the economic burden and to support local communities by transferring the economic benefits to them through ecotourism, hunting and employment besides the compensation system, which helps alleviate the negative feelings towards predators, as they also profit from their presence (SILLERO-ZUBIRI, et al. 2004). An example is the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) in Zimbabwe, which promotes conservation through giving the income generated from hunting, game-watching and curio sales, directly to the landholders in the community (SILLERO-ZUBIRI and SWITZER, 2004). The opinion of the public is always important in the promotion of wolf conservation, which can be improved through tourism and education; however, this must always be fact-based and accurate (HUBER et al., 1999). One such establishment is the Wolf Science Center in Austria, which does scientific research, educates and involves the public through programmes and activities. Through these methods the opinion of the public can shift and novel methods of generating an added income to affected livestock owners can be used, such as adding a premium price to goods marketed as "predator-friendly" farms, when they use non-lethal management techniques (SILLERO-ZUBIRI and SWITZER, 2004). Livestock insurance is another possibility, where the insurance company can include the parameters, like the management methods that can decrease the risk of predation, in their premiums. This protects the livelihood of the livestock owner, while also promoting the implementation of non-lethal anti-predation methods (SILLERO-ZUBIRI and SWITZER, 2004).

In some countries the compensation system is extended to dogs too, such as Norway, where this system has been in place since 1999 and the compensation is for the dogs' actual market value, which could be as much as €5,000 (LIBERG et al., 2010).

In reaction to the major issue experienced by hunters, in relation to wolf attacks on hunting dogs, Norwegian hunters have developed their own form of prevention called the "Wolf Telephone". This system is used during hunting season and is an answering machine which is constantly updated with the approximate locations of the wolves' last radio location. Then it is up to the hunter to choose to avoid those areas that day or to take the risk. Of course, it does not completely prevent encounters as there are wolves which are not collared and we must also consider the fact that wolves can move through the terrain quite quickly, but it is a step in the right direction on the part of the hunters, to look for their own methods to increase their and their dogs' safety (LIBERG et al., 2010).

A more common response from the public is to demand the reduction of numbers or the extermination of the wolf. Even as far back as 6th century BC, Athens began the system of state bounties for the killing of wolves, to reduce their numbers and protect livestock. (SILLERO-ZUBIRI et al., 2004). In North America colonists deliberately hunted wolves and coyotes to the verge of extinction in most US territories, with the only exceptions being Minnesota and Alaska, which were the only areas which maintained viable populations (SILLERO-ZUBIRI and SWITZER, 2004). In the USA it is still possible for landowners or their delegates, to kill wolves considered problematic within 8km of their land without permission and hunters don't need a special permit to be able to kill wolves (MUHLY et al., 2010).

Fortunately, today the importance of wolves as part of the food web and their role in ecosystem is recognised. This helped the shift towards alternative modes of dealing with wolf related problematic situations (HUBER et al., 1999). In the meantime, it has been hypothesized that wolves that prey on livestock, do so through a learned behaviour, much like the man-eating tigers in India. Once the animal has a successful interaction it begins to consider it a new, alternative prey species (LINNELL et al., 2000). This in turn would suggest that removing the culprit individual may be more efficient than population control (SILLERO-ZUBIRI et al., 2004). The Global Positioning System (GPS) and satellite telemetry collars on individuals can help tie a specific wolf attack to an individual or to a pack specifically, and they can be tracked in the future to assess the threat they pose. In Norway, the idea is the culling of individuals and the constant analysis of the change in depredation patterns without eliminating the entire pack (LIBERG et al., 2010). However, we must be aware of the difficulty in identifying a problem individual when we speak of a pack animal, which decreases the chances of successful extraction (ADAMIČ et al., 2004). In Scandinavian countries it has become a routine requirement to collect DNA samples from the targeted offender, to evaluate its genetic value before permission is given to cull the animal, thus also taking into consideration the value of the animal on a population level (LIBERG et al., 2010). However, there is ongoing debate about the efficacy of culling, as studies have shown that for each wolf killed, there is a 2.2% increase in sheep depredation in the same year (POUDYAL et al., 2016). The removal of wolves cannot reduce or stabilize depredation cases unless there is a steady state in the predator population of an area (KOMPANIYETS and EVANS, 2017). It has been shown that partial pack removal leads to no difference in consequent depredation rates after 14 days, when compared to no action taken at all against the perpetrator (BRADLEY et al., 2015).

Many studies have been conducted into the management and topographical parameters that can increase or decrease the chances of predation on a certain farm. One study used logistic regression and Resource Selection Functions to identify the characteristics in the habitats, that lead to increased risk of depredation and thus created a livestock depredation probability map, with the aim of highlighting the areas where anti-depredation methods should be focused (MUHLY et al., 2010). Another method of prediction is the creation of a wolf population simulation model, which if continually updated can be a highly effective warning device (LIBERG et al., 2010).

3. Materials and methods

3.1 Reliability of data

When a livestock owner contacts the competent authorities in the occurrence of depredation of his/her livestock, a trained official is sent to assess the damages and determine which large carnivore could have been the perpetrator, distinguishing between wolves (*Canis lupus*), bears (*Ursus arctos*), lynx (*Lynx lynx*) or dogs (*Canis lupus familiaris*). As the assessment of damages is made by trained officials and the fact that reporting such damages are in favour of the livestock owner, the dataset is considered reliable.

The ministry has compiled a vast dataset, which has been presented in several excel tables. I have used 3 of these tables, one which has data on wolf predation cases between 2010-2020, including information on location of attack, date of attack, species attacked, numbers killed and/or wounded per attack and the degree of protection measures taken by the livestock owner. The second table contained information on the time of day of the attacks while the last one contained information on the species of large carnivore behind each attack in the period between 2010-2020.

3.2 Study Area

In Croatia, each attack on livestock by a predator is reported by the owner to the competent authorities, which collect the necessary data on each attack. This data is collected and assessed by the Ministry of Economy and sustainable development. Firstly, the locations of the attacks are marked by coordinates, settlement names, municipality, and county. Using this data, I grouped the attacks by counties to identify the most affected areas over the period of 2010-2020. I then removed the outliers, which were the counties with under 25 cases of attacks within said period. Cases with incomplete data were excluded. I grouped the counties into three areas; North, which included Sisačko-moslavačka, Karlovačka, and Primorsko-goranska counties which covered an area of 10628 km^2. Central Croatia was the area of Ličko-senjska county covered 5230 km^2, and South which included Zadarska, Šibensko-kninska, Splitsko-dalmatinska and Dubrovačko-neretvanska counties, covered a total area of 10752 km^2.

3.3 Statistical Analysis

To assess the possible seasonal and diurnal changes regarding the likelihood of predation, I divided the case reports by month and by the time of the day when depredation occurrence to see if any fluctuations are seen in different seasons. The reports also included data on the time of day the attacks occurred, which were marked as morning, day, evening, night or unknown. I calculated the number of cases within each category to allow for the assessment of any period in the day having an increased likelihood of depredation occurrence over others. I used the Two-way Chi squared test to compare the seasonal and daily differences in predation.

As officials must assess each case in detail to determine the predator, which was behind each attack, I could assess and compare the numbers of attacks by each large carnivore, to see the magnitude of damage caused per species of predator. I used the Two-way Chi squared test to compare the differences of predation frequencies by different predator.

Officials note the perpetrator but also the species attacked and how many were injured and killed in each case. I used this data to compare the numbers of attacks by domestic prey species, to see which preference of prey, if any, would exist for wolves. I then compared the numbers of killed and injured animals to see the success rate of livestock depredation of wolves. I used the Two-way Chi squared test to compare the differences of wolf predation frequencies by different species of domestic animals and the proportion of killed vs. injured animals.

Since damage inspectors assess the environment of the attack, they also get to evaluate the prevention methods in place on each farm. Unfortunately, the database records did not provide details regarding type of fences, presence of a shepherd, guard dog breeds or numbers, etc. so a detailed analysis of the efficacy of each measure was not possible. The protocol which damage inspectors follow includes all those details, but the administrators in the responsible ministry simplify the details of the protocol and from the detailed description of damage inspectors, they make their own summary conclusion, which fall into one of three categories of guarding levels: 1- the owner has implemented protection measures, 2- the owner has partially implemented prevention measures, 3- the owner did not implement protection measures. Using this, I compared the number of depredation cases by degree of protection in each county, to see which areas have the most prevention methods in place.

I compared the degree of protection measures used in the cases of the different livestock species. Using the Mann-Whitney U-test I assessed the significance of the frequencies in the number of attacks, comparing them with the degree of livestock guarding. Using the Mann-Whitney U-test again, I also compared the average numbers of livestock killed in different counties when prevention measures were implemented as opposed to when they were not. The significance level was at $p<0.05$ for both tests.

To assess the relationship between the population density of each species per region with the number of wolf attacks in those regions, I chose to use the Chi-squared test. First, I organized the data by livestock species (cattle, sheep, goats, horses, donkeys) attacked per county and the year of attack between 2010-2020. I calculated the number of animals of each species of domestic animal per region and divided it by the area of the region to get the population density. I gathered data from the Ministry of Agriculture's public data, on the number of each species kept per county for the given period. Then for each species, I calculated the number of attacks per region for 2010-2020 and divided it by the area of that region. Using these two numbers I could assess if there was a statistically significant relationship between the density of livestock in given areas and the numbers of attacks seen in those areas. First, I analyzed the relationship between regions for each species in pairs (North - Central, North - South, Central - South), then a combination of all three regions (North, Central and South) at once and finally I did the same for all species at once. The results were considered statistically significant at $p<0.05$.

4. Results

4.1 Livestock damage cases by the predator species

The total number of the recorded attacks by large carnivores between 2010-2020 was 15,751. Lynxes were responsible for 6 (0.04%), bears for 10 (0.06%) and dogs for 55 (0.35%) of these cases, while wolves were by far the most frequent predators (n=15,137, 96.1%). There were 543 (3.45%) cases where the predator was not determined. This could change the numbers, but it would still not be enough to remove wolves from the leading species of large carnivore causing livestock depredation in Croatia.

A Two-way Chi squared test was performed to test the differences comparing the frequency of wolf attacks and other species of carnivores, showed that the difference between the number of reported livestock depredation cases per species of large carnivores identified as the perpetrator was significant ($\chi 2=28480.678$, DF=3, $P < 0.0001$).

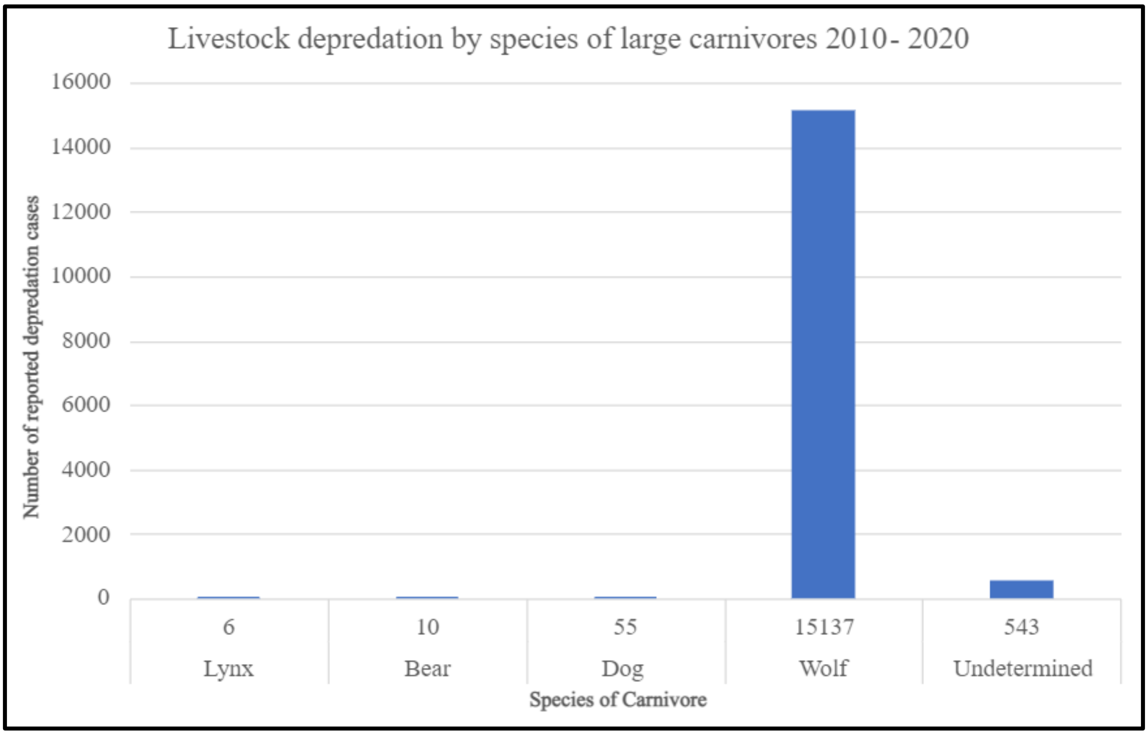

Figure 1.: Number of reported livestock depredation cases per species of large carnivores identified as the perpetrator in the period of 2010-2020

4.2 Wolf attacks by counties and regions

In Croatia, when a case of livestock depredation is reported, the competent authorities collect data which provides the location of the attack. Using this data, I grouped the wolf attacks by counties, to identify the areas most affected in the period of 2010-2020. I then removed the outliers, which were the counties with under 25 cases of wolf attacks within said period, namely Bjelovarsko-bilogorska (n=8), Istarska (n=17), Virovitičko-podravska (n=1), Vukovarsko-srijemska (n=0), Zagrebačka (n=3). An additional three cases with incomplete data had to be excluded, as the location of the wolf attack was not marked, another five were excluded because the domestic species attacked was not written.

After removing the outliers, all the remaining counties had more than 25 wolf attacks in 10 years. The total number of cases analyzed for all counties was 18,116. The Southern region had the greatest number of attacks (n=17,144; 94.6%), more specifically Zadarska county (n=3,373; 18.6%*),* Šibensko-kninska county (n=7,330; 40.5%), Splitsko-dalmatinska county (n=6,050; 33.4%), and Dubrovačko-neretvanska county (n=391; 2.2%). The Central region i.e. Ličko-Senjska county, had only 732 (4%) cases, while the North region had 240 (1.3%) wolf attacks of which Primorsko-goranska county had 80 (0.4%), Karlovačka county had 33 (0.2%) and Sisiačko-moslavačka county had 127 (0.7%) of all wolf attacks (Figure 1).

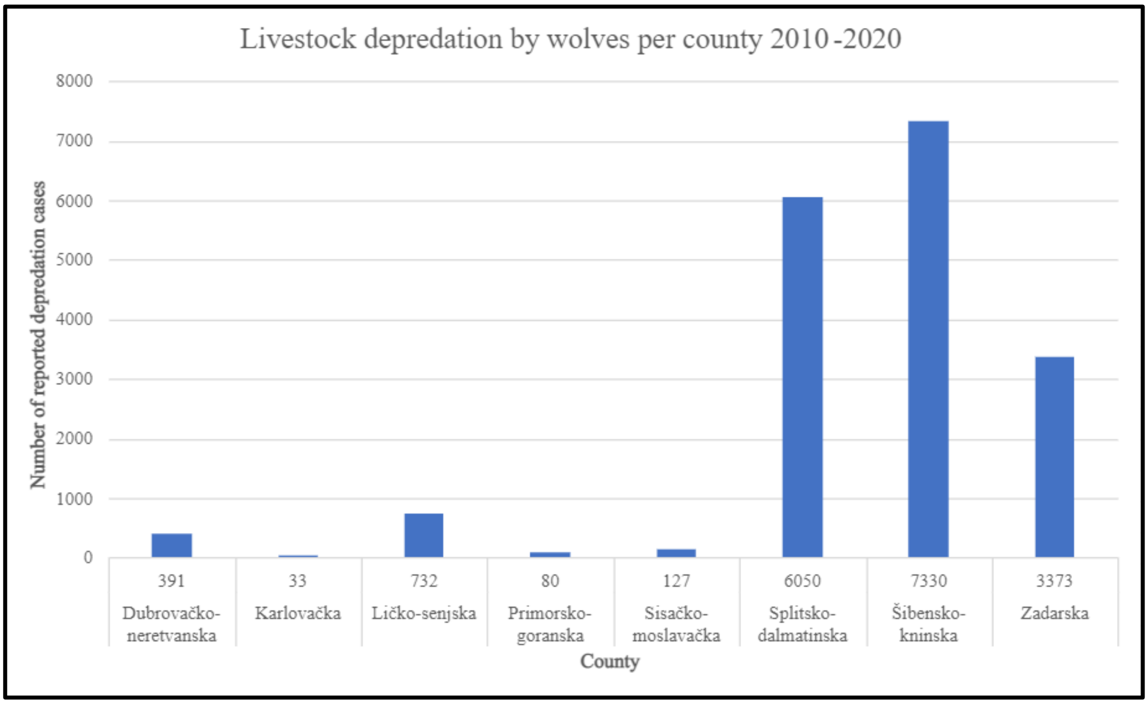

Figure 2.: Number of reported livestock depredation cases by wolves per county in the period of 2010-2020

4.3 Seasonal and diurnal patterns of wolf attacks on livestock

As the date of the wolf attacks was noted for 18,116 cases, it was possible to determine a trend through seasons, indicating that the winter months (n=3,326; 18.36%) had the lowest occurrence of depredation, with a steady increase in spring (n=4,369; 24.11%) until a peak in the summer (n=5,531; 30.53%). The highest number of cases was seen in July (n=1,890; 10.43%) and August (n=1,997; 11%), followed by a steady decline through Autumn (n=4,890; 27%) to the lowest rate of attacks during the winter months. This indicates that the summer months were the times of highest risk of depredation on livestock.

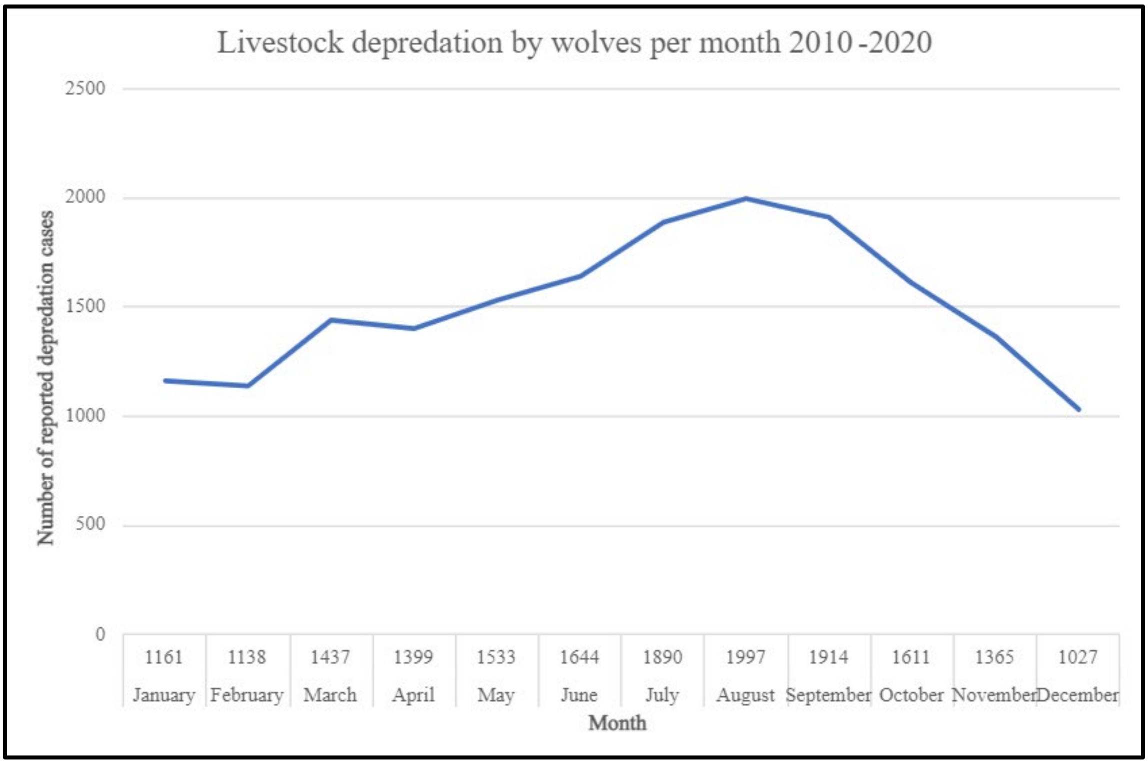

Figure 3.: Number of reported livestock depredation cases by wolves per month of occurrence in the period of 2010-2020

The time of day of the wolf attacks was noted for 15,132 cases, as one of four categories: morning, day, evening and night. Morning (n=5,144; 34%) and daytime (n=5,518; 36.5%) cases were dominant throughout the years, making up 70.5% of all wolf attacks, while wolf attacks in the evening were less frequent (n=2,212; 14.6%) with the lowest attack frequency at night (n=617; 4.1%). For 1,641 (10.9%) cases, the time of the day when the attacks happened was not known.

With the Two-way Chi-square test comparing the frequencies of attacks per time of the day, the difference between the number of livestock depredation cases by wolves per time of day was found to be significant ($\chi2=4206.028$, DF=3, $P < 0.0001$).

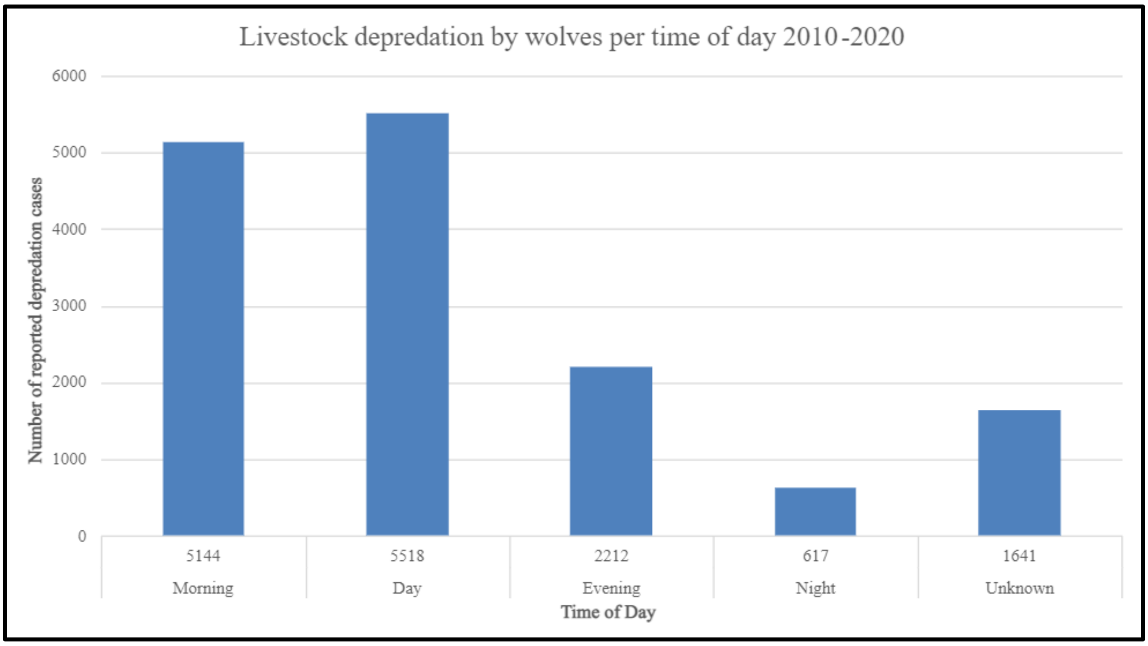

Figure 4.: Number of reported livestock depredation cases by wolves per time of day in the period of 2010-2020

4.4 Wolf attacks by species of domestic animals

In the period between 2010-2020, a total of 18,116 cases were recorded by the species of domestic animals attacked by wolves. Attacks on rams (n=16; 0.09%) and lambs (n=19; 0.1%) were included with sheep, foals (n=1; 0.006%) were included with horses, kids (n=4; 0.02%) and bucks (n=3; 0.02%) were included with goats, calves (n=12; 0.07%) were included with cattle, mules (n=1; 0.006%) and hinnies (n=3; 0.02%) were included with donkeys. Overall, the greatest number of casualties was documented on sheep (n=10,457; 57.7%), then goats (n=3,606; 19.9%) and cattle (n=2,407; 13.3%). Horses (n=182; 1%) and donkeys (n=336; 1.9%) were less represented, while pigs appeared in only 20 (0.1%) cases. Dogs although not livestock species were still represented as an important domestic animal, which had 1108 (6.1%) wolf depredation cases.

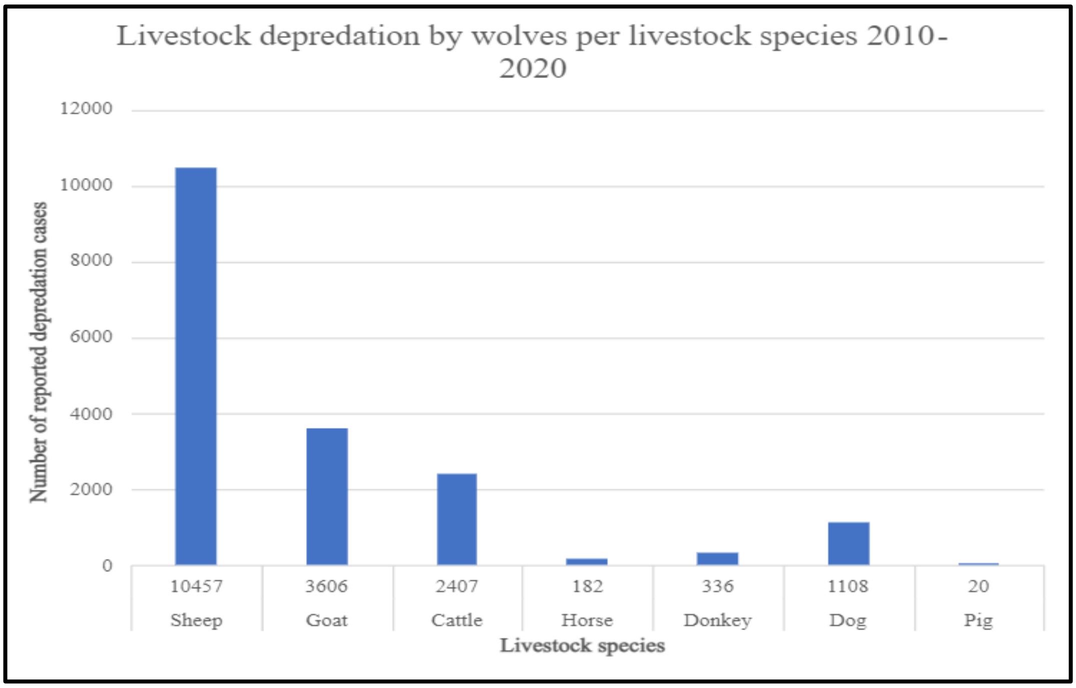

Figure 5.: Number of reported livestock depredation cases by wolves per species of livestock attacked in the period of 2010-2020

4.5 Wolf attacks by location

Depredation cases where the location of the attack is marked (n=18,116), in most cases occurred on the pasture (n=16,334; 90.2%) and to a lesser extent in fenced areas (n=477; 2.6%). There were 438 (2.4%) unmarked case reports, with an additional 867 cases (4.8%) of cases marked as 'other'.

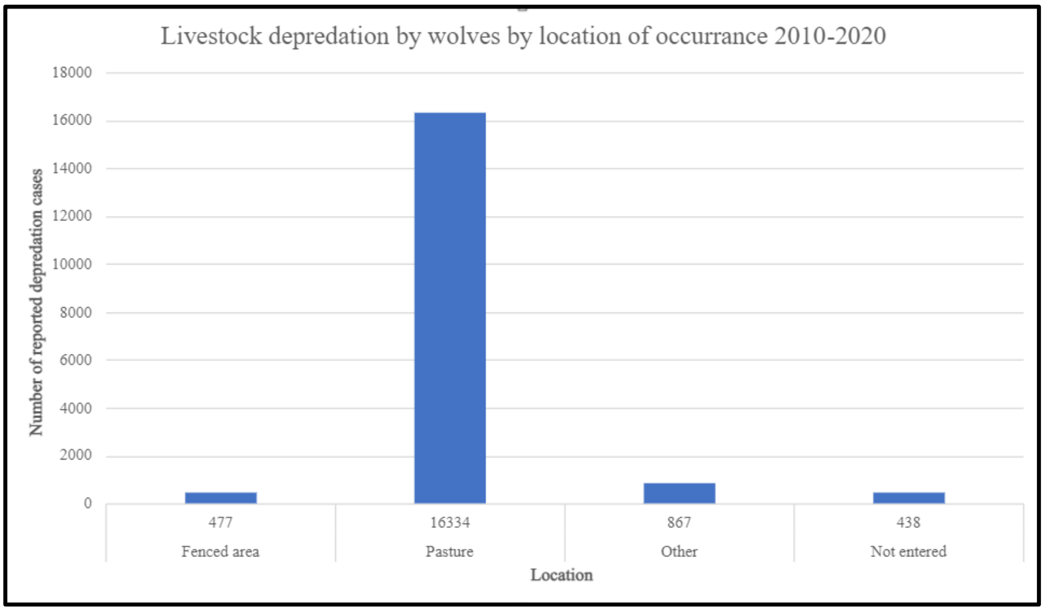

Figure 6.: Number of reported livestock depredation cases by wolves per location of livestock attacked in the period of 2010-2020

4.6 The ratio of wounded to killed livestock in wolf depredation cases

The total number of animals wounded by wolves in this period was 24,735 (81.3%) and killed was 5,703 (18.7%). The difference between the number of killed and injured animals was found to be significant with a Two-way Chi-squared test ($\chi 2=119.011$, DF=1, $P<0.0001$).

The average number of livestock killed or wounded per attack was 1.68 individuals. The average number of livestock killed per attack were 0.31 individuals, while the average number of livestock animals wounded per attack were 1.37 individuals.

When looking at sheep specifically, the average number of animals killed per attack was 0.4, while the average number of sheep injured per attack was 1.55 individuals. The average number of sheep killed or injured in an attack was 1.95 individuals.

For goats the average number of animals killed per attack was 0.3, while the average number wounded was 1.29. The average number of goats wounded or killed in an attack was 1.59.

In the case of cattle, the average number of animals killed per attack was 0.1, while wounded per attack was 0.98. The average number of cattle wounded or killed per attack was 1.08.

For horses the average number of animals killed per attack was 0.21, while the average wounded was 0.91. The average number of horses wounded or killed per attack was 1.13.

In the case of donkeys, the average number of animals killed per attack was 0.17 and wounded was 0.95, while the average of killed or wounded was 1.12.

When looking at dogs, the average number of animals killed per attack was 0.12, the average wounded was 0.9, while the average number killed or wounded was 1.02.

In the case of pigs, the average number of animals killed per attack was 0.45, while wounded was 0.95. The average number of animals wounded or killed was 1.4.

Table 1.: The average numbers of domestic animals killed, wounded and killed or wounded, per case of depredation

	Number killed	Number wounded	Number of attacks	Average killed	Average wounded	Number wounded or killed	Average wounded or killed
Sheep	4,133	16,235	10,457	0.40	1.55	20,368	1.95
Goat	1,086	4,638	3,606	0.30	1.29	5,724	1.59
Cattle	249	2,359	2,407	0.10	0.98	2,608	1.08
Horse	39	166	182	0.21	0.91	205	1.13
Donkey	58	318	336	0.17	0.95	376	1.12
Dog	129	1,000	1,108	0.12	0.90	1,129	1.02
Pig	9	19	20	0.45	0.95	28	1.4
TOTAL	5,703	24,735	18,116	0.31	1.37	30,438	1.68

4.7 Comparation of livestock density and the numbers of wolf attacks

Comparing the availability of species of livestock with their representation in damage cases between different regions, statistically significant differences were found. The difference in proportions of wolf attacks of each group of animal species when comparing North-Central, Central-South, North-South and North-Central-South regions was significant at the level of $p<0.05$. The only exception being donkeys in the case of North-South regions.

The proportion of wolf attacks on all domestic livestock species in the South was significantly higher than in the North and Central regions ($\chi 2 = 1099.58$, $p < 0.05$, DF = 1). Also, the proportion of wolf attacks in the North was significantly higher than in the Central region ($\chi 2 = 22.20$, $p < 0.05$, DF=1).

Table 2: Chi-square comparation among regions, using the availability (density, n/km^2) of livestock and intensity of wolf damage (n/km^2) per species of livestock. In all testing pairs the degree of freedom was 1 and significance threshold was at 0.05.

	Cattle		Sheep		Goats		Horses		Donkeys		All animals	
Regions comparation	Chi-square	Sig. level	Chi-square	Sig. level	Chi-square	Sig. level	Chi-square	Sig. level	Chi-square	Sig. level	Chi-square	Sig. level
North-Central	394.18	P < 0,0001	9.89	P = 0.0017	26.37	P < 0.0001	6.74	P = 0.0094	6.79	P = 0.0092	22.20	P < 0,0001
Central - South	995.06	P < 0,0001	1779.64	P < 0.0001	117.08	P < 0.0000	66.01	P < 0,0001	7.74	P = 0.0054	301.14	P < 0,0001
North-South	4491.28	P < 0,0001	365.25	P < 0.0001	424.23	P < 0.0001	478.91	P < 0,0001	0.58	P = 0.4481	632.6	P < 0,0001
North-Central -South	5204.7	P < 0,0001	2000.48	P < 0,0001	533.15	P < 0,0001	485.29	P < 0,0001	8.73	P = 0.0127	1099.58	P < 0,0001

4.8 The comparation of the species of livestock attacked with the degree of protection measures implemented.

The average number of head of livestock killed per attack by wolves per county where prevention measures were present (n= 15,607; 86%), was 1.31 when taking all counties into account, while in cases where prevention measures were not implemented (n= 1,666; 9.2%), the average number of livestock killed per attack was 1.59. I did a Mann-Whitney U-test using the average number of livestock killed per county when implementing protection measures and when not. At $p<0.05$, the difference was shown not to be significant as $p=1.46$.

Table 3: Prevention measures implemented per county and the number of cases of depredations, minimum and maximum heads of livestock killed per attack and average number of livestock killed per attack

County	Protection Measures	Number of Cases	Min. killed	Max. killed	Average killed
Dubrovačko-neretvanska	Not reported	40	1	9	1.875
	The owner has **partially** implemented prevention measures	11	1	6	1.545
	The owner **has implemented** prevention measures	301	1	15	1.631
	The owner **did not** implement prevention measures	41	1	4	1.219
Karlovačka	Not reported	1	3	3	3
	The owner has **partially** implemented prevention measures	2	2	10	6
	The owner **has implemented** prevention measures	18	0	62	4.722
	The owner **did not** implement prevention measures	12	1	15	5
Ličko-senjska	Not reported	12	1	3	1.454
	The owner has **partially** implemented prevention measures	11	1	20	6.545
	The owner **has implemented** prevention measures	696	0	53	2.021
	The owner **did not** implement prevention measures	15	1	3	1.933
Primorsko-goranska	Not reported	2	1	1	1
	The owner has **partially** implemented prevention measures	31	1	7	1.548
	The owner **has implemented** prevention measures	19	1	13	3.263
	The owner **did not** implement prevention measures	32	0	30	2.75
Sisačko-moslavačka	Not reported	7	1	5	1.857
	The owner has **partially** implemented prevention measures	20	1	7	2.3
	The owner **has implemented** prevention measures	54	0	15	3.574
	The owner **did not** implement prevention measures	46	0	11	3.413
Splitsko-dalmatinska	Not reported	202	0	13	1.635
	The owner has **partially** implemented prevention measures	140	1	7	1.257

County	Protection Measures	Number of Cases	Min. killed	Max. killed	Average killed
	The owner **has implemented** prevention measures	5061	0	84	1.555
	The owner **did not** implement prevention measures	655	0	22	1.535
Šibensko-kninska	Not reported	95	1	27	2.621
	The owner has **partially** implemented prevention measures	79	1	10	1.506
	The owner **has implemented** prevention measures	6592	0	31	1.462
	The owner **did not** implement prevention measures	579	0	23	1.977
Zadarska	Not reported	107	1	37	4.745
	The owner has **partially** implemented prevention measures	117	1	18	2.752
	The owner **has implemented** prevention measures	2867	0	58	1.824
	The owner **did not** implement prevention measures	286	0	24	3.381

Among the farms attacked, the highest case numbers were seen among farms which had implemented prevention measures (n=15,607; 86%) and the lowest cases were seen in farms which had only partially implemented prevention measures (n=411; 2.3%). Farms which had not implemented prevention measures, also had a significant number of cases (n=1,666; 9.2%), even if well below that of the farms that did have prevention measures.

Table 4.: The preventive measures implemented by farmers and the number of depredation cases by category of measures implemented, partially implemented, or not implemented for prevention.

Damage prevention measures	Number of cases
The owner **has implemented** prevention measures	15,607
The owner has **partially** implemented prevention measures	411
The owner **did not** implement prevention measures	1,666
Not reported	462
TOTAL	18,146

When dividing the case numbers by two parameters, security measures and counties, we can see that farms which took the permitted actions and measures had the most cases in 3 specific counties, namely Zadarska (n=2,867; 15.8%), Šibensko-kninska (n=6,592; 36.3%), Splitsko-dalmatinska (n=5,061; 27.9%). As these counties are the ones of the highest numbers of depredation throughout Croatia, it is expected that the cases would reflect this, regardless of the measures taken. We can see that in all three groups regardless of the level of prevention measures implemented, these three counties have the highest number of attacks in all cases.

Table 5.: The number of wolf attacks by counties and by the degree of prevention measures implemented by counties

	The owner **has implemented** prevention measured	The owner has **partially** implemented prevention measured	The owner **did not** implement prevention measured	Not reported
Dubrovačko-neretvanska	301	11	41	40
Karlovačka	18	2	12	1
Ličko-senjska	696	11	15	11
Primorsko-goranska	19	31	32	2
Sisačko-moslavačka	54	20	46	7
Splitsko-dalmatinska	5,061	140	655	200
Šibensko-kninska	6,592	79	579	95
Zadarska	2,867	117	286	106
TOTAL	15,607 (86%)	411 (2.3%)	1,666 (9.2%)	462 (2.5%)

Using the Mann-Whitney U-test I compared the significance of the presence and absence of prevention measures taken by the livestock owner, using the number of wolf attacks on each domestic animal species. The significance level was placed at $p < 0.05$ and the result of the calculation was $P=0.13$, concluding that there is evidence of the measures taken not making a significant difference in depredation of the various livestock species kept in Croatia.

Table 6.: Number of wolf attacks per domestic animal species regarding degree of implemented prevention measures

Animals attacked	The owner **has implemented** prevention measured	The owner has **partially** implemented prevention measures	The owner did **not implement** prevention measures	Not reported
Sheep	9,399	160	685	227
Goat	3,303	41	176	87
Cattle	1,628	158	555	71
Horse	101	13	60	11
Donkey	232	13	74	18
Dog	929	21	112	48
Pig	15	5	0	0
TOTAL	15,607	411	1,666	462

5. Discussion

We can see that by far, sheep were the species of domestic animals with the highest numbers in Croatia and as this study showed, by far greatest number of livestock depredation cases was seen among sheep. The preference of wolves for sheep, contrary to larger prey as horses or donkeys reflects the opportunistic nature of the wolf as a predator, for which it is known that it attacks the prey which is easier to subdue and kill (MECH et al., 2015). In areas where a different livestock species is dominant, such as Spain, where we see far more intensive cattle rearing and far fewer small ruminants, cattle were the livestock species predominantly attacked by large carnivores (KACZENSKY, P., 1999), but there is no information about the age class of attacked cattle. Apart from this area (Cantabrian Mountains, Spain), in all 13 countries analyzed by KACZENSKY, sheep and goats were the species of livestock most often targeted by all three large carnivores (KACZENSKY, P., 1999). In Slovakia in 2004, the reported livestock losses in 44% of cases were sheep and goats with an average loss of 3.1 sheep to wolves and 0.7 to bears per flock, while cattle and horses only accounted for 11% (RIGG et al., 2011). The loss of 1.68 animals per attack in Croatia is nearly two folds less than in Slovakia, which indicates that wolves had less time for pursuing and killing the prey. This indicates generally better livestock guarding in Croatia compared to Slovakia. In Sweden sheep are also the most targeted livestock species, with about 500 sheep killed or injured yearly, while other species are seldom attacked and cattle, goats and poultry together, make up a meagre 1-4% of the annual livestock losses (WIDMAN and ELOFSSON, 2018).

In Croatia, the total number of animals wounded by wolves in the study period was almost a quarter of those killed, indicating that most of the time domestic animals can't defend themselves from an attack or that livestock owners most often don't have a chance to interrupt the attack. In Slovakia interviews with livestock owners have shown that in some cases, shepherds are alerted to an attack in time and can chase away the predators, while in other cases the predators will kill the sheep despite their efforts with the use of firecrackers, lamps, etc., as predators can get habituated to such items (RIGG et al., 2011). The Slovakian higher number of killed sheep per attack and the fact that the use of lamps and firecrackers is common, but not helpful, tells us they keep livestock on the open at night, with inadequate or no use of livestock guarding dogs whatsoever, which in combination with an adequate number of shepherds present, provides proper protection (KUSAK and ŞEKERCIOGLU, 2021). In other cases, the attacks are only discovered after feeding (RIGG et al., 2011).

As sheep are the most common target of livestock depredation by large carnivores, for sheep specifically the average number of animals killed per attack was 0.4, while the average number of sheep injured per attack was 1.55 individuals. Interestingly, the study of wolf diet in Croatia (OCTENJAK et al., 2020), shows that not sheep but goats are the most frequent species of domestic animals being eaten by wolves. The discrepancy may be because of how sheep and goats behave and are guarded while outside of stables or pens. Sheep graze on open pastures, while goats browse leaves of low trees, bushes, such as exists in most of Dalmatia. When sheep are attacked, most of the carcasses can be found and thus it can be proven to have been killed by wolves. On the contrary, goats browsing in dense chaparral are harder to guard, easier for wolves to prey on and harder for the owner and the damage inspector to find the remains and prove the wolf attack. The average number of sheep killed or injured in an attack was 1.95 individuals. In a study conducted in Slovenia, wolves killed or injured an average of

5.1 sheep per attack (n = 188), with a range of 1- 40 animals (ADAMIČ et al., 2004). When analysing the same parameters for Croatia, I found that the average was 1.95 sheep killed or wounded per attack (n=10,457 cases), with a range of 1-62 animals. As the average number of sheep wounded or killed in Slovenia is almost double that of Croatia, this proves that the tradition of sheep guarding in Croatia is more efficient than in Slovenia.

When comparing farms which suffered from depredation cases, it was found that the highest case numbers were seen among farms which had implemented prevention measures (n=15,607; 86%) and the lowest cases were seen in farms which had only partially implemented measures (n=411; 2.3%).

Farms which had not implemented measures also had a significant number of cases (n=1666; 9.6%). However, when dividing the case numbers by two parameters, security measures and counties, we could see that farms which took the permitted actions and measures had the most cases in 3 specific counties, namely Zadarska (n=2,867; 15.8%), Šibensko-kninska (n=6592; 36.3%), Splitsko-dalmatinska (n=5,061; 27.9%) counties. As these counties are the ones of the highest numbers of depredation throughout Croatia, it is expected that the cases would reflect this, regardless of the measures taken. We can see that in all three groups based on implementation of prevention measures, these three counties have the highest number of attacks in all cases. Using the Mann-Whitney U-test I compared the significance of the presence and absence of prevention measures made by the livestock owner, using the number of animals attacked per species, which showed that the degree of prevention measures taken did not make a significant difference in depredation of the various livestock species kept in Croatia ($p=0.14$, significance level $p<0.05$). With the second Mann-Whitney U-test I compared the different counties based on whether they did or did not implement prevention measures and the average number of livestock killed, which showed that there was no significant difference in the degree of prevention measures implemented and the number of animals killed ($p=0.13$). As we see in Germany, the number of wolf depredation cases are decreasing, indicating that the adaptations of livestock owners and authorities by increasing prevention measures have been successful (SINGERA et al., 2022). In Croatia, the number of attacks per year was steady, in the range between 1400 to 1500 per year, indicating a stable state of livestock husbandry. However, in the most recent years, the number of cases in Croatia reached 2000 per year. This is coincident with the increased subsidies and number of unguarded cattle within wolf range in Croatia. Studies have shown that depredation levels are not directly correlated to the number of predators in the case of bears in Spain, nor the number of livestock available as a source of prey, but rather the differences in the local husbandry practices (KACZENSKY, P., 1999). However, there simply isn't enough scientific research conducted into the efficacy of individual intervention measures used to prevent the depredation of livestock by large carnivores (n = 21) (EKLUND et al., 2017). Some studies suggest that an increase in wild prey and the implementation of prevention measures could reduce livestock depredation of wolves significantly (JANEIRO-OTERO et al., 2020). This is in accordance with the study of wolf diet in Croatia (OCTENJAK et al., 2020), which proved that wolves preferred wild prey over domestic animals, in spite of its lower availability. However, a large-scale trial on the efficacy of each livestock protection measure is still needed, as information is lacking on their use, since authorities only record the protection measures used in the case of an incident, which does not provide enough information on efficacy (SINGERA et al., 2022).

This study has shown that wolves were by far the most frequent predators (n=15,137) in Croatia, when compared to livestock depredation of lynx (n=6) and bears (n=10), which is a pattern seen across Europe. A study comparing livestock depredation in 13 European countries found that of the 13 countries analyzed, the highest livestock losses were caused by wolves when compared to other large carnivores (KACZENSKY, P., 1999). In Slovakia, wolves caused an estimated annual loss of livestock (n= 1,625) 5.6 times that of bears (n=290), while annual livestock losses to lynx were negligible (n=4) (RIGG et al., 2011). However, one country in Europe where the opposite pattern is seen is Norway, where bears cause twice as much damage as wolves (KACZENSKY, P., 1999). The reason for this is that Norway tolerates only maximum of five wolf packs in the country, of which two need to be transboundary with Sweden (BISCHOF et al., 2019). Only in certain areas, where the only large predator is the lynx (Switzerland, Czech Republic, French Jura Mountains) or it is in far greater numbers than other large carnivores native to Europe, was it the dominant cause of livestock predation (KACZENSKY, P., 1999)

In this study, the highest number of livestock depredation cases was seen in July (n=1,890; 10.43%) and August (n=1,997; 11%), followed by a steady decline to the lowest rate of attacks during the winter months (n=3,326; 18.36%). This indicates that the summer months (n=5,531; 30.53%) were the times of highest risk of depredation on livestock, which could be corelated with the change in management methods between seasons, as in warmer periods of the year livestock are kept on pastures, while during colder periods they are kept in stables and closer to inhabited buildings. This hypothesis is supported by the fact that the reported depredation cases, where the location of the attack is marked, mostly occurred on the pasture (n=16,334; 90.2%) and to a lesser extent in fenced areas (n=16,334; 90.2%). In seasonal environments it is expected that the predation patterns vary between seasons, due to the shift in prey availability and vulnerability, however, such seasonal variations are poorly understood (METZ et al., 2012). Seasonal changes also encompass different weather conditions, however, other than precipitation, weather showed to have little effect on movement and activity patterns of collared wolves in Ontario (KOLENOSKY and JOHNSTON, 1967). They saw that wolves who preferred to travel during the day and others, which preferred to travel during the night, did so regardless of temperature or cloud cover and, to a smaller extent, precipitation (KOLENOSKY and JOHNSTON, 1967). However, in the Mediterranean climate, the daily activity of wolves is proven to be affected by temperature, where wolves were proven to be less active in the mid-days during summers, compared to higher mid-day activity during winter days (KUSAK et al., 2005). When analyzing the activity patterns of wolves, several factors need to be considered, such as human activity, prey availability, reproduction and weather, which vary greatly among geographical areas, thus leading to differences in activity patterns in various study sites. (THEUERKAUF et al., 2003).

6. Conclusion

- By reported number of livestock depredation cases of large carnivores in Croatia, we can see that the Southern regions (n=17,144; 94.6%) was significantly more affected than North (n=240; 1.3%) or Central (n=732; 4%) areas of Croatia. As the data set was lacking in many respects, we could not at this time determine what the exact reason for this was. Further information on management methods, terrain, distance from inhabited areas, wolf population size and wildlife prey population abundancy would need to be analyzed to create an accurate image of factors influencing the hot spots of attacks. This could in turn be used to create more effective preventive measures to decrease the likelihood of depredation.
- In Croatia, summer months (n=5,531; 30.53%) were with the highest likelihood of livestock depredation by wolves, while winter months (n=3,326; 18.36%) were the lowest.
- The 'morning' and 'daytime' were the periods of the day with the highest likelihood for wolf depredation, when compared to the 'evening' or 'night-time' in Croatia.
- In Croatia, among large carnivores responsible for cases of livestock depredation, wolves were the species causing the highest number of attacks.
- Among livestock species attacked by wolves, sheep (n=10,457; 57.7%), goats (n=3,606; 19.9%) and cattle (n=2,407; 13.3%) received the greatest numbers of depredation cases.
- Most livestock depredation cases caused by wolves, occurred on pastures (n=16,334; 90.2%) and to a lesser extent in fenced areas (n=16,334; 90.2%).
- The total number of animals wounded by wolves in this period was 24,735 (81.3%) and killed was 5,703 (18.7%). The average number of livestock killed or wounded per attack was 1.68 individuals. The average number of livestock killed per attack was 0.31 individuals, while the average number of livestock animals wounded per attack was 1.37 individuals.
- Using the Chi-squared test to show the relationship between the number of attacks per species (cattle, sheep, goats, horses, donkeys) per region (North, Central, South) and density of livestock per region, we concluded that the differences in proportions of wolf attacks on each group of animal species, except donkeys, comparing North-Central, Central-South, North-South and North-Central-South regions was significant. For all animals, the proportion of wolf attacks in the South was significantly higher than in the North and Central regions. Also, the proportion of wolf attacks in the North was significantly higher than in the Central region.
- The measures taken did not make a significant difference in how many animals were affected by wolf attacks.
- The average number of head of livestock killed per attack per county, where prevention measures were present was 1.31, while in cases where prevention measures were not implemented, the average number of livestock killed per attack was 1.59. The difference was not significant.
- However, further analyses on the efficacy of specific livestock protection measures in the different regions of Croatia are needed, to provide complete information for livestock owners and authorities, so they can optimize the prevention methods and consequently reduce the number of depredation cases in the country.

7. Bibliography

1. ADAMIČ, M., K. JERINA, M. JONOZOVIČ (2004): Problems connected with the large-carnivore conservation in Slovenia: Did we find the right way?, Game Wild. Sci. 21, 571–580.
2. BACKERYD, J. (2007): Wolf attacks on dogs in Scandinavia: Will wolves in Scandinavia go extinct if dog owners are allowed to kill a wolf attacking a dog?. Master thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden. 175, 1-21.
3. BISCHOF, R., C. MILLERET, P. DUPONT, J. CHIPPERFIELD, M. ÅKESSON, H. BRØSETH, J. KINDBERG (2019): Estimating the size of the Scandinavian wolf population with spatial capture-recapture and conversion factors. Norwegian University of Life Sciences, MINA fagrapport. 57, 1-80.
   DOI: 10.13140/RG.2.2.22066.25283
4. BOITANI, L., P. CIUCCI (2009): A New Era for Wolves and People - Wolf Recovery, Human Attitudes, and Policy: 1.1, In: Wolf Management across Europe: Species Conservation without Boundaries. (M. Musiani, L. Boitani, P. C. Paquet, Eds.), 15-39. DOI: 10.1017/S0962728600002165
5. BOJOVIĆ, D., D. COLIĆ (1973): Wolves in Yugoslavia with special reference to the period 1945-1973. In: Proc. First Working Meeting of Wolf Specialists. (D. H. Pimlott, Eds.), 43, 53-61.
6. BRADLEY, E. H., H. S. ROBINSON, E. E. BANGS, K. KUNKEL, M. D. JIMENEZ, J. A. GUDE, T. GRIMM (2015): Effects of wolf removal on livestock depredation recurrence and wolf recovery in Montana, Idaho, Wyoming. J. Wildl. Manage. 79, 1337-1346.
   DOI: 10.1002/jwmg.948
7. ČERNE, R., M. KROFEL, M. JONOZOVIČ, A. SILA, H. POTOČNIK, M. MARENČE, P. MOLINARI, J. KUSAK, T. BERCE, M. BARTOL (2019): A Fieldguide for Investigating Damages Caused by Carnivores: Brown Bear, Grey Wolf, Golden Jackal, Red Fox and Eurasian Lynx. Slovenia Forest Service, Life Dinalp Bear project. 1-88.
8. CHAPRON G., P. KACZENSKY, J. D. LINNELL, M. VON ARX, D. HUBER, H. ANDRÉN, J. V. LÓPEZ-BAO, M. ADAMEC, F. ÁLVARES, O. ANDERS, L. BALČIAUSKAS, V. BALYS, P. BEDŐ, F. BEGO, J. C. BLANCO, U. BREITENMOSER, H. BRØSETH, L. BUFKA, R. BUNIKYTE, P. CIUCCI, …, L. BOITANI (2014): Recovery of large carnivores in Europe's modern human-dominated landscapes. Sci. (New York, N.Y.). 346, 1517–1519.
   DOI: 10.1126/science.1257553
9. CIUCCI, P., BOITANI, L., FRANCISCI, F., & ANDREOLI, G. (1997): Home range, activity and movements of a wolf pack in central Italy. J. Zool. 243, 803-819.
   DOI: 10.1111/J.1469-7998.1997.TB01977.X
10. CIUCCI, P., M. MASI, L. BOITANI (2003): Winter habitat and travel route selection by wolves in the northern Apennines, Italy. Ecography. 26, 223-235.
    DOI: 10.1034/J.1600-0587.2003.03353.X
11. CLARK, K. R. F. (1971): Food habits and behavior of the tundra wolf on central Baffin Island. PhD thesis, University of Toronto, Toronto, Canada.
12. COZZA, K., R. FICO, M. L. BATTISTINI, E. ROGERS (1996): The damage-conservation interface illustrated by predation on domestic livestock in central Italy. Biol. Cons. 78, 329-336.
    DOI: 10.1016/S0006-3207(96)00053-5
13. DECESARE, N. J., S. M. WILSON, E. H. BRADLEY, J. A. GUDE, R. M. INMAN, N. J. LANCE, K. LAUDON, A. A. NELSON, M. S. ROSS, T. D. SMUCKER (2018): Wolf-

livestock conflict and the effects of wolf management. J. Wildl. Manag. 82, 711–722. DOI: 10.1111/j.1469-1795.2009.00328.x
14. DORRANCE, M. J. (1982): Predation losses of cattle in Alberta. In: J. Range Manag. 35, 690-692.
DOI: 10.2307/3898239
15. EKLUND, A., LÓPEZ-BAO J., TOURANI M., CHAPRON G., FRANK J. (2017): Limited evidence on the effectiveness of interventions to reduce livestock predation by large carnivores. Sci. Rep. 7, 2097.
DOI: 10.1038/s41598-017-02323-w.
16. ESPUNO, N., B. LEQUETTE, M-L. POULLE, P. MIGOT, J-D. LEBERTON (2004): Heterogeneous Response to Preventive Sheep Husbandry during Wolf Recolonization of the French Alps. Wildl. Soc. Bull. 32, 1195–1208.
DOI: 10.2193/0091-7648(2004)032[1195:HRTPSH]2.0.CO;2
17. FRKOVIĆ, A., Đ. HUBER (1995): Vuk u Hrvatskoj. In: Volk ne ogroža - volk je ogrožen (urednik Adamič, M.), Društvo Kočevski naravni park, Kočevje. 27-33.
18. GEIST, V. (1999): Adaptive strategies in American mountain sheep: effects of climate, latitude and altitude, ice age evolution, and neonatal security. In: Mountain sheep of North America (R. Valdez and P. R. Krausman, Eds.), 192–208.
DOI: 10.2307/j.ctv21wj58s.
19. HEPTNER, V. G., N. P. NAUMOV, P. B. YURGENSON, A. A. SLUDSKII, A. F. CHIRKOVA, A. G. BANNIKOV (1998): Mammals of the Soviet Union. Vol. II, part 1a. Sirenia and Carnivora (sea cows; wolves and bears). Vysshaya Shkola Publishers. Moscow, Russia.
DOI: 10.1086/374485
20. HUBER, Đ., J. KUSAK, D. KOVAČIĆ, A. FRKOVIĆ, J. RADOVIĆ, Ž. ŠTAHAN (1999): Privremeni Plan Gospodarenja Vukom u Hrvatskoj.
21. JANEIRO-OTERO, A., NEWSOME T. M., VAN EEDEN L. M., RIPPLE W. J., DORMANN C. F. (2020): Grey wolf (Canis lupus) predation on livestock in relation to prey availability. Bio. Cons. 243.
DOI: 10.1016/j.biocon.2020.108433
22. JĘDRZEJEWSKI, W., K. SCHMIDT, J. THEUERKAUF, J. BOGUMIŁA, R. KOWALCZYK. (2007): Territory size of wolves Canis lupus: Linking local (Białowieża Primeval Forest, Poland) and Holarctic-scale patterns. Ecography. 30, 66–76.
DOI: 10.1111/j.0906-7590.2007.04826.x
23. JEREMIĆ, J., S. DESNICA, A. ŠTRBENAC, D. HAMIDOVIĆ, J. KUSAK, Đ. HUBER, G. CHAPRON, G. GUŽVICA OIKON DOO, H. POTOČNIK, T. SKRBINŠEK (2014): Report on the state of the wolf population in Croatia in 2014. State Institute for Nature Protection, Zagreb, Croatia.
24. Kaczensky, P. (1999): Large Carnivore Depredation on Livestock in Europe. Ursus. 11, 59–71.
25. KOLENOSKY, G. B., D. H. JOHNSTON (1967): Radio-Tracking Timber Wolves in Ontario. Integr. Comp. Biol. 7, 289-303.
26. KOMPANIYETS, L., M. A. EVANS (2017): Modeling the relationship between wolf control and cattle depredation. PLoS ONE. 12.
DOI: 10.1371/journal.pone.0187264
27. KUSAK, J. (1997): Farmer kills rabid wolf. Eu. Wolf Newsl. 5, 2–2.
28. KUSAK, J., A. M. SKRBINŠEK, D. HUBER, A. M. SKRBINSEK, D. HUBER (2005): Home ranges, movements, and activity of wolves (Canis lupus) in the Dalmatian part of Dinarids, Croatia. Eu. J. Wildl. Res. 51, 254–262.
DOI: 10.1007/s10344-005-0111-2

29. KUSAK, J., Ç. H. ŞEKERCIOĞLU (2021): Large carnivores and livestock in northeastern Turkey: a pragmatic coexistence. Carniv. Dam. Prev. News. 1–9.
30. KUSAK, J., Đ. HUBER, S. RELJIĆ, A. MAJIĆ-SKRBINŠEK, T. SKRBINŠEK, L. ŠVER, M. HABAZIN (2019): Stručna podloga za izradu prijedloga plana upravljanja vukom. Zajednica ponuditelja: Udruga Carnivora Magna, Biotehnološki fakultet Sveučilišta u Ljubljani (Slovenija) i Geonatura d.o.o.
31. KUSAK, J., E. FABBRI, A. GALOV, T. GOMERČIĆ, H. ABRANASIĆ, R. CANIGLIA, M. GALAVERNI, S. RELJIĆ, D. HUBER, E. RANDI (2018): Wolf-dog hybridization in Croatia. Vet. Arh. 88, 375-395.
DOI: 10.24099/VET.ARHIV.170314
32. LIBERG, O., Å. ARONSON, S. M. BRAINERD, J. KARLSSON, H-C. PEDERSEN, H. SAND, P. WABAKKEN (2010): The Recolonizing Scandinavian Wolf Population: Research and Management in Two Countries. In: The world of wolves - new perspectives on ecology behaviour and management (Muisani M., Boitani L., Paquet P. C., Eds.), 175-207.
33. LINNELL, J. D. C., R. ANDERSEN, Z. ANDERSONE, L. BALCIAUSKAS, J. C. BLANCO, S. BRAINERD, U. BREITENMOSER, I. KOJOLA, O. LIBER, J. LOE, H. OKARMA, H. C. PEDERSEN, C. PROMBERGER, H. SAND, E. J. SOLBERG, H. VALDMANN, P. WABAKKEN (2002): A fear of wolves: A review of wolf attacks on humans. NINA Oppdragsmelding. 731, 1-65.
34. MECH, D. L. (1988): Longevity in wild wolves. J. Mammalology. 69, 197–198.
DOI: 10.2307/1381776
35. MECH, L. D., D. W. SMITH, D. R. MACNULTY (2015): Wolves on the Hunt: The Behavior of Wolves Hunting Wild Prey. University of Chicago Press.
36. MECH, L. D., R. O. PETERSON (2003): Wolf-prey relations. In: Wolves: behavior, ecology, and conservation (L. D. Mech and L. Boitani, eds.), 131–57.
37. MECH, L. D., S. H. FRITTS, G. L. RADDE, W. J. PAUL (1988): Wolf distribution and road density in Minnesota. Wildl. Soc. Bull. 16, 85-87.
38. METZ, M.C., SMITH, D.W., VUCETICH, J.A., STAHLER, D.R. AND PETERSON, R.O. (2012): Seasonal patterns of predation for gray wolves in the multi-prey system of Yellowstone National Park. J. Anim. Eco. 81, 553-563.
DOI: 10.1111/j.1365-2656.2011.01945.x
39. MUHLY T., C. C. GATES, C. CALLAGHAN, M. MUSIANI (2010): Livestock Husbandry Practices Reduce Wolf Depredation Risk in Alberta, Canada. In: The world of wolves - new perspectives on ecology, behaviour and management (Muisani M., Boitani L., Paquet P. C., Eds.), 235-261.
40. OCTENJAK, D., L. PAĐEN, V. ŠILIĆ, S. RELJIĆ, T. T. VUKIČEVIĆ, J. KUSAK (2020): Wolf diet and prey selection in Croatia. Mamm. Res. 65, 647-654.
DOI: 10.1007/s13364-020-00517-8
41. PAQUET P. C., S. ALEXANDER, S. DONELON, C. CALLAGHAN (2010): Influence of Anthropogenically Modified Snow Conditions on Wolf Predatory Behaviour. In: The world of wolves – new perspectives on ecology behaviour and management (Muisani M., Boitani L., Paquet P. C., Eds.) 157-175.
42. PAQUET, P. C. (1989): Behavioural ecology of sympatric wolves (Canis lupus) and coyotes (C. latrans) in Riding Mountain National Park, Manitoba. Ph.D. Dissertation, University of Alberta, Edmonton, Canada.
DOI: 10.7939/R3XW48743
43. PETERSON, R. O., P. CIUCCI (2003): The wolf as a carnivore, In: Wolves: behavior, ecology, and conservation (L. D. Mech and L. Boitani, eds.), 104–130.

44. PLATIŠA, M., I. PINTAR, J. KUSAK (2011): Body features of gray wolf (Canis lupus L.). Veterinar: časopis studenata veterinarske medicine Zagreb 49, 16–27.
45. PLUMER, L., T. TALVI, P. MÄNNIL, U. SAARMA (2018): Assessing the roles of wolves and dogs in livestock predation with suggestions for mitigating human–wildlife conflict and conservation of wolves. Cons. Gen., 19, 665–672.
DOI: 10.1007/s10592-017-1045-4
46. POUDYAL, N., N. BARAL, S. T. ASAH (2016): Wolf Lethal Control and Livestock Depredations: Counter-Evidence from Respecified Models. PLoS ONE. 11.
DOI: 10.1371/journal.pone.0148743
47. RIGG, R., S. FINĎO, M. WECHSELBERGER, M. GORMAN, C. SILLERO-ZUBIRI, D. MACDONALD (2011): Mitigating carnivore–livestock conflict in Europe: Lessons from Slovakia. Oryx. 45, 272-280.
DOI: 10.1017/S0030605310000074
48. SILLERO-ZUBIRI, C., D. SWITZER (2004): Management of wild canids in human-dominated landscapes. In: Canids: Foxes, wolves, jackals and dogs (Sillero-Zubiri, Hoffmann M., Macdonald D. W., Eds.), 257-266.
49. SINGERA, L., WIETLISBACHA X., HICKISCHD R., SCHOELLE E. M., LEUENBERGERC C., VAN DEN BROEKF A., D´ESALMEG M., DRIESENH K., LYLYI M., MARUCCOJ F., KUTALK M., PAGONM N., PAPPN C. R., MILIONIO P., UZDRASP R., ZIHMANISQ I., ZIMMERMANNR F., MARSDENS K., HACKL¨ANDERE K., L´OPEZ-BAOT J. V.,KLENZENDORFU S., WEGMANNA D. (2022): The spatial distribution and temporal trends of livestock damages caused by wolves in Europe. Cold Spring Harbor Laboratory.
50. ŠTREBANC, A., Đ. HUBER, J. KUSAK, A. MAJIĆ-SKRBINŠEK, A. FRKOVIĆ, Ž. ŠTAHAN, J. JEREMIĆ-MARTINKO, S. DESNICA, P. ŠTRBENAC (2005): Wolf Management Plan for Croatia: Towards understanding and addressing key issues in wolf management planning in Croatia. State Institute for Nature Protection, Republic of Croatia.
51. THEUERKAUF, J. (2009): What Drives Wolves: Fear or Hunger? Humans, Diet, Climate and Wolf Activity Patterns. Ethology. 115, 649-657.
DOI: 10.1111/j.1439-0310.2009.01653.x
52. THEUERKAUF, J., JĘDRZEJEWSKI, W., SCHMIDT, K., OKARMA, H., RUCZYŃSKI, I., ŚNIEŻKO, S., & GULA, R. (2003): Daily patterns and duration of wolf activity in the Białowieża forest, Poland. J. Mammalogy. 84, 243–253.
DOI: 10.1644/1545-1542(2003)084<0243:DPADOW>2.0.CO;2
53. TIKKUNEN, M., I. KOJOLA (2019): Hunting dogs are at biggest risk to get attacked by wolves near wolves' territory boundaries. Mammal Res. 64, 581–586.
DOI: 10.1007/s13364-019-00444-3
54. WIDMAN, M., K. ELOFSSON (2018): Costs of Livestock Depredation by Large Carnivores in Sweden 2001 to 2013. Ecol. Econ. 143, 188-198.

8. Abstract

Dynamics of wolf predation on livestock in Croatia

Irisz Koutis

Damages caused by protected wild carnivores, such as the wolf, are compensated in Croatia and therefore, collected data on the cases of wolf depredation could be used to analyze a range of recorded parameters of attacks. The period of 2010-2020 was selected, as it had the most complete dataset for the needed parameters. Seasonal changes in depredation were analyzed, showing that the highest number of cases occurred in summer (n=5,531; 30.53%), while the lowest number of attacks happened in winter (n=3,326; 18.36%). Diurnal analyses of wolf attacks showed that wolves in Croatia are mostly attacking livestock during the day (n=5518). It was found that wolves were the greatest cause of livestock depredation (n=15,137) and their target species were most often sheep (n=10,457; 57.7%). Most wolf attacks occurred on the pastures (n=16,334; 90.2%) with the average number of livestock killed or wounded per attack being 0.8 individuals. The average number of livestock killed per county when implementing protection measures as opposed to cases where prevention measures were not implemented, was not significant. The number of livestock attacked, with and without prevention measures implemented, based on species attacked was found not significant. Comparing the availability of species of livestock with their representation in damage cases between different regions, statistically significant differences were found. Statistically non-significant differences were only seen for donkeys when comparing North-South regions.

Key words: wolf; livestock; depredation; Croatia

9. Sažetak

Dinamika napada vukova na stoku u Hrvatskoj

Irisz Koutis

Štete uzrokovane zaštićenim divljim zvijerima, poput vuka, u Hrvatskoj se nadoknađuju pa se prikupljeni podaci o slučajevima napada vuka mogu koristiti za analizu niza zabilježenih parametara napada. Odabrano je razdoblje 2010-2020, jer je za to razdoblje postojao najpotpuniji skup podataka za potrebne analize. Analizirane su sezonske promjene u predaciji, pokazujući da je najveći broj slučajeva bio tijekom ljeta (n=5,531; 30.53%), a najmanji zimi (n=3,326; 18.36%). Dnevne analize napada vukova pokazale su da su vukovi u stoku u Hrvatskoj najčešće napadaju danju (n=5518). Utvrđeno je da su vukovi bili najveći uzročnici šteta na stoci (n=15.137), a najčešće napadana vrsta stoke bila je ovca (n=10,457; 57.7%). Većina napada vukova dogodila se na pašnjacima (n=16,334; 90.2%) s prosječnim brojem ubijenih ili ranjenih grla od 0,8 jedinki po napadu. Analiziran je prosječan broj stradale stoke

po županijama kada su se provodile mjere zaštite i kada nisu, te se pokazalo da razlika nije bila značajna. Nije bilo značajne razlike u broju napadnute stoke s obzirom na primjenu preventivnih mjera. Uspoređujući raspoloživost stoke s učestalošću šteta između različitih regija utvrđene su statistički značajne razlike. Uspoređujući Sjevernu i Južnu regiju značajna razlika nije utvrđena za magarce.

Ključne riječi: vuk; stoka; predacija; Hrvatska

10. Curriculum Vitae

My name is Irisz Koutis and I was born in Hungary but was essentially raised across Europe, finally finishing my high school education at the European School of Brussels I. Later, in 2016 I enrolled in the Faculty of Veterinary Medicine at the University of Zagreb.

Since I started my university education I have always made a point of contributing my time and efforts wherever I could, through working with Associate Prof. Đuras to create illustrations for the *"Protocol of activities in the case of finding a stranded, injured or dead dolphin" (2018)*, through taking part in events such as Zoonosis Summer School in Dubrovnik *(2017)*, the Plavi Projekt *(2019)*, '*Entrepreneurial Mindset, Open to Innovation workshop*' *(2020), and* through volunteering at Open days *(2018)*, Night of Museums *(2018,2019)*, Veterinary Science and Profession Congresses *(2019)* and even the events of the celebration of the 100 years of the faculty *(2019)*.

I was the first international student who joined the editorial board of the Veterinar, which gave me a chance to increase the number of articles available in English. Within my time at Veterinar our work was recognised and granted the Rector's award.

Later, some of my colleagues and I decided to create the Vet Society to help integrate the two language sections. I was also the Exchange Officer of IVSA Croatia and along with our president, we worked tirelessly and managed to raise the standing of IVSA Croatia to 5th place out of 194 member organisations worldwide during our time.

Later, I took part in two papers of the Department of Anatomy and Histology one of which was on the *"Growth and osteological development of two Croatian common carp (Cyprinus carpio L) strains – preliminary study"* which won the poster competition at the 32nd Conference of the EAVA in Hanover, Germany. The other was about the "*Durable anatomical specimens as a replacement for formalin-fixed specimens in the anatomy courses"* which was presented at the YGVA held in Bucharest, Romania where my colleague, Juliette Magoga and I also presented a poster about the work of the Vet Society in the anatomy student's room.

During the summer semester of 2020 I started working on a research paper on the host-parasite interactions of the red deer, with Professor D. Konjević and my dear colleague, Juliette Magoga.