UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

WolfRadar

Sebastian Orgel,2786885
David de Groot, 3048489
Rares Ioan-Ionescu, 2800462
Sylvia Zhao, 2649780
Ewoud Janus, s2395762
Fleur Groot Nibbelink, s2861550
Ekaterina Koshkina, s2647842
Theo van den Berg, s2654652

UNIVERSITEIT TWENTE.

Table of Contents

Chapter 0: Introduction

As society adjusts to a more sustainable future, the relationship between humanity and nature has to be redefined. The age of humans conquering nature and controlling it might finally come to an end, as we suffer the consequences of controlling and manipulating it. One example of humans trying to alter their environment to their liking are wolves. For 10.000 years wolves have been a natural part of Eurasia and we are only starting to understand the direct and indirect impacts of these apex predators in regulating the balance of nature.

In the Middle Ages, the efforts to exterminate wolves in Europe started and grew increasingly organized. There were bounties on wolves in Sweden in the late 17th century, and entire forests have been burned down to get rid of the dangerous animal that attacked livestock and threatened humans. At that time, the public regarded wolves as dangerous beasts that serve no purpose, except being hunted for the warm fur they supply. This has been the case for all large carnivores in Europe at that time.
These efforts continued until the wolf became extinct in the mid 20th century, with only a small population surviving in Scandinavia and France. With that, the benefits to the environment the wolf supplies as an apex predator have also been lost.

Since then, repopulation of wolves into modern Europe has been a topic of much debate and controversy in recent years. Wolves were once a common sight throughout Europe, but their populations declined dramatically over time due to habitat loss and persecution by humans. In an effort to restore the balance of nature and promote biodiversity, some European countries have made efforts to reintroduce wolves back into the wild.

One way that the repopulation of wolves can be managed is through the use of smart collars that monitor the location and behavior of the animals. These collars transmit data on the location of the wolf to a database called WolfRadar, allowing researchers to track the movements and behavior of the animals in real-time. By analyzing this data, researchers can better understand how wolves are adapting to their new environments and how they are interacting with other species.

In addition to monitoring the wolves, these smart collars also have the ability to prevent serious harm or damage done by the animals. For example, if a wolf approaches a farm or livestock, the collar can send an alert to the farmer, giving them the opportunity to take preventative measures to protect their animals.

The repopulation of wolves has not been without its challenges and controversies. Some farmers and livestock owners have opposed the reintroduction of wolves, fearing that they may attack and kill their animals. However, proponents of wolf repopulation argue that the benefits of having wolves in the ecosystem, such as controlling populations of deer and other herbivores, outweigh the potential risks.

One of the main goals of the WolfRadar is to improve the public perception of wolves and promote coexistence between wolves and humans. By using the data collected from the smart collars, researchers can work to better understand the behavior and needs of wolves, and use this information to educate the public about these animals. By increasing understanding and awareness, it is hoped that the public will be more accepting of wolves and that wolves and humans can live alongside each other without conflict.

Overall, the repopulation of wolves into modern Europe is a complex and multifaceted issue that requires careful consideration and management. By using smart collars and other monitoring techniques, researchers and conservationists can work towards a better understanding of these animals and their role in the ecosystem, while also taking steps to prevent harm and damage caused by wolves.

Chapter 1: Literature Review

Below you find summaries of 23 publications on the subject of wildlife monitoring.

There's wildlife research in the south of the Netherlands, using wildlife cameras, artificial intelligence and geographic information systems. By doing this they can take action when a species is not doing that well. They use multiple cameras and store the coordinates of animals in a database [1].

Researchers at Wageningen University made a design for a camera system in the national park: De Hoge Veluwe. It cites what kind of equipment they would use, why to implement it and how they would process the data [2].

A bee-measurement system and app for beekeepers. The system has sensors that measure the weight, temperature and sound of the bee colony. The information is automatically transferred to the BEEP app. In the app you can see the data and take measures when some data is off [3].

In their paper Marcot and Heyden present various ecological functions of wildlife with a WHR focus, where WHR is a concept of wildlife being a function of habitat. The work discusses key ecological functions of different species, as well as presents a variety of graphs like total functional diversity and richness that can be a great starting point to identifying the topic for a project [4].

The website presents different threats to wildlife of today. It can be easily spotted that most of the problems wildlife experience nowadays are caused by human intervention. Articles from this website can be a great start for building an educational campaign to promote the project [5].

Roads are the second largest source of anthropogenic mortality for many vertebrates. more than a million animals are estimated to be killed on the roads in the USA per day. Roads affect the way animals travel and make new barriers where animals can or can not live. Roads also have an influence on where different species come because the roads have a way to figure as a barrier. This also gives an attribute to less biodiversity and will result in invasive species [6].

To understand the complex interactions among animals within an ecosystem, biologists need to be able to track their location and social interactions. There are a variety of factors that make this difficult. It proposes using adaptive, embedded networked sensing technologies to develop an efficient means for wildlife monitoring. This paper surveys our research; By demonstrating how a self-organizing system can efficiently conduct real-time acoustic source detection and localization using distributed embedded devices [7].

Camera equipment has allowed researchers to study a range of species, including rare and elusive species. The article speaks about how to improve in the future and identifying countries and habitat types of focus and how terrestrial wildlife is conducted in Africa [8].

The barred owl's expansion has resulted in negative impacts to spotted owls and forest ecosystems. With the use of recording units they studied this expansion. With sliding window template detectors they identified territorial vocalizations. Unlike vocal-lure surveys, this does not alter owl behavior and vocalization.
With this way of monitoring it is possible to create a new data set, containing classification of vocalizations. Combining this technique with others, you can investigate the interaction and community between species [9].

Invasive rodents are threatening ecosystems of islands around the globe. This paper investigates the monitoring of rodents using bite marks. They look at the bite marks on hard seedcases that remain after the seed is eaten. This way of monitoring is successful, even when there is enough food supply on the islands. The method was less efficient in detecting rats compared to traditional methods, but more efficient in detecting mice.
This new way of monitoring rodents can be used for long-term and low-cost monitoring [10].

This paper compares ground based counting methods with remotely piloted aircrafts, to determine which is more accurate. For this research replica seabird colonies were placed. The number of birds in the colonies was determined and used to calculate the methods' accuracy. The number of seabirds in the high quality images of the drones was both counted manually and semi-automated. Although the manual approach of reviewing the images was more accurate, the difference is not big.
Compared to ground based counting methods drones were far more accurate [11].

This research paper resulted in richness, diversity and abundance in species from West-Africa, over the two years it took. There were 20 mammal species observed, another three were not detected by the cameras and 13 photographed species were not included in the patrol data [12].

The monitoring of beehives becomes more feasible as the capability of sensors and other electronic equipment increases and material costs decrease. These can be used by researchers to better understand the population and other metrics important to the health of the beehive, such as weight, temperature, humidity, and vibration.
There are four main groups of sensors used to monitor beehives, such as, (1) weight; (2) temperature, humidity, and gas; (3) sound and vibration; and (4) forager traffic. Weighing the beehive is considered to be harmless to the beehive and results in data that is easy to understand and analyze, as well as cheap from cost perspective [13].

To combat the decline in global biodiversity, biomonitoring is necessary to provide an accurate picture of the species present in any given environment.
Using air samples in a natural environment, DNA extracted from the air samples was able to identify 25 distinct species and furthermore identify known predator-prey relationships of endangered species. The development of vast DNA databases and the improvement of sensor capabilities have made it possible to take DNA from air samples and rapidly identify

the current species present in any given environment without the intrusive effects of capturing live animals.
DNA is shed from all organisms and in the past, aquatic biodiversity monitoring has been revolutionized by monitoring environmental DNA. Now, this technique is used to monitor air samples from a zoological park. This paper aims at providing solid ground for future research. In total, 2.7 million non-human DNA sequences have been collected. Analyzing the data under less than optimal laboratory conditions suggests that there is a proof-of-concept for doing these kinds of experiments in the wild [14].

Monitoring biodiversity is important to identify the loss of any terrestrial species in any given environment. In this study, air samples using a volumetric air sampler have been installed across five locations across Italy in order to collect environmental DNA for metabarcoding. This data is used to understand the biodiversity of plants and fungi.
Using High-throughput screening, the researchers were able to identify the different DNA sequences of the animals present in the field, as well as using a DNA database to identify specific species from a multitude of biological material such as spores, pollen, and several plant fragments [15].

To comprehend biodiversity losses and create successful conservation strategies, dedicated long-term monitoring at the proper geographical and temporal scales is required. In order to understand the status, trends, and drivers of specific species or entire communities, as well as their dynamics, wildlife monitoring is frequently accomplished by collecting data at a variety of spatial scales, ranging from local to large. However, choices in the nature and volume of data collecting are necessary due to the monitoring's limited resources. For monitoring programs that cover many spatial scales, careful consideration of the spatial and temporal allocation of finite sample effort is essential [16].

UAVs(unmanned aerial vehicles) have shown their capacity to quickly and efficiently perform high-quality and low-disturbance wildlife aerial surveys, especially in tough or challenging environments . However, it has often proven to be quite time-consuming to classify or count the species of interest from the vast quantities of imagery collected during the flights. Despite increased effort in this field, other important difficulties continue to exist, including UAV regulations, operational costs, and public perception.
In order to find wildlife in its native habitats, a system that combines UAVs with thermal imaging capabilities and ai - powered image processing is described in this work as a solution to the issue of automated animal detection in UAV footage [17].

The use of an artificial neural network (ANN) combined with microcontrollers to create a robust and lower power consumption way of tracking animals. The ANN collects data from an IMU sensor, with the use of different microcontrollers to get the lowest power consumption with an accuracy of 97.96% ± 1.42%, and an energy efficiency of 450 Mop/s/watt. A nice combination of wildlife tracking and the IOT [18].

High accuracy and highly efficient animal recognition using deep convolutional Neural Network. Being able to use camera traps as a tool for wildlife monitoring is a great help, however it creates huge amounts of data to go through. Manually going through this data is not feasible. Here the deep convolutional neural network architecture is able to train on data and return with an accuracy of 96.6% [19].

Animal tracking using IOT, arduino, gsm etc… For sensing, communication and relative hardware for zoology and biology. Using acceleration gyro sensors, temperature, humidity, height, wind, light and or camera powered by a solar panel (different types of sensors for different animals). A more diverse and modular system of tracking different types of animals [20].

Chapter 2: Identification of General Problems and Challenges

Below you find different problems and challenges derived from a discussion after Chapter 1.

- Threatening wildlife:

Humankind has made it difficult for some animals or plants to thrive. This is done not only by hunting, but also reducing their optimal living conditions. This puts additional hardships on weakened ecosystems. Increased Urbanization and the usage of land for agricultural purposes has been responsible for a loss of habitable land for animals and plants.

- Decline in bee population:

The bee population is declining and is at risk of extinction. This is concerning because bees play a large role in pollinating plants.Some plants are only pollinated by Bees and essentially use them and their behavior as a reproductive vehicle. This issue is self-reproducing and is made worse by monocultures and loss of biodiversity stemming from human agriculture. Wild grassland with many different plants is an optimal breeding ground for bees and not many of these are left.

- Human based monitoring:

The simplest way of monitoring animals is human based monitoring. You can imagine a person looking at a population of an animal and counting them. This way of monitoring has been used over and over and created a large database of wildlife knowledge. But as we all know humans are not perfect, their senses can be faulty. With the boost in technology, it is interesting to find new ways of monitoring wildlife that is not human based.

- General loss of biodiversity:

As alluded to earlier, some problems are self-reproducing and interact with multiple other problems on this list. One of the most prevalent and important is the general loss of biodiversity. Due to several factors biodiversity is decreasing. These are including, but not limited to: Urbanization, Agricultural use of land and the resulting reduction in wild living areas, climate change and the effects of a warming planet and all its cascading effects, and monoculture forests for economic use. All of these have detrimental effects for animals and plants and self-reproducing, for example, a monoculture forest can only provide resources for animals that are adapted to that specific type of forest. This can mean that certain groups of animals have better living conditions, which again, can have negative effects down the food chain.

- Invasive species:

Invasive species are species that are not native to a particular area. The reason why invasive species are present in a certain area is mostly due to humans bringing animals into an area where they do not belong. This has been done in the past to fight a certain animal or problem using other animals or defending economic security against wild animals. This has been done without consulting the complex predator-prey relationships and can sometimes and in chaos. Invasive species can introduce diseases into the biosphere that other animals present are not used to. For example, the feral hog was introduced to Texas 300 years ago and now they are responsible for millions of dollars in damages to farmland.

- Roadkills:

Over the years, road infrastructure has increased. Oftentimes, these roads are going through forests and other farmland habitat to millions of birds and mammals. In Europe alone, there are 194 million small birds and 29 million mammals that are killed by Cars. Monitoring these roadkills could give more information about the number of roadkills but also the distribution of a species.

- Obtrusive observation:

Although monitoring any wildlife is beneficial to gain knowledge, not all wildlife is easily monitored. A reason for this is challenging environments. It can be too difficult or dangerous to monitor certain wildlife. The future of technology can possibly overcome these obstacles. Monitoring wildlife can also have negative effects like disturbance. Firstly, disturbing living things is something to always avoid. Secondly, disturbing it can change their behavior and therefore make the data unreliable. Unmanned aerial vehicles have already been used as a low-disturbance way of monitoring. A more unobtrusive way of monitoring wildlife is needed to gather accurate data about animals and their behavior for further research and protection without falsifying the data.

- Reduction of Old-growth forests:

Old-growth forests are forests that are not cut or used in any other economical way, and basically are left to themselves with minimal disturbance. Many people don't recognize that modern forests are mostly used for economical purposes and are therefore home to a selective breed of trees and hence, are home to a limited number of plants and animals. All over the world Old-growth forests are decreasing like in Brazil in which the largest area of old-growth forest is cut each year. In Europe, only one small area of old growth forest, the Bialowieza Forest, in eastern Poland is left and is home to around 800 european bison.

Chapter 3: Identification of Relevant Problems

Listed below are 5 new problems derived from the previous chapter.

- Frog monitoring:

Frogs are very important for influencing water. Small frogs eat algae which helps clear the water. This has a big influence on the life that is in and out of the water. That can be measured how many frogs are in certain areas with a sensor. It placed the sensors in the frog tunnels that are normally used for frogs to cross the road safely. The number of frogs contributes in a good way because it indicates the health of an ecosystem.

- Bird migration:

Sometimes it is hard to identify if the birds started their migration journey. Even if the date of their approximate arrival is known, birds do not have a concrete schedule. To solve the problem of uncertainty we want to place sound sensors in common places of bird migration, to make it possible to track the behavior of birds.

- Soil moisture:

Soil moisture is responsible for regulating soil temperature and nutrient delivery and prevents soil erosion. Climate change has caused global temperatures to rise with unprecedented speed. Because of this soil moisture is decreasing.
Low soil moisture is associated with an increase in insect and pathogen outbreaks as well as wildfires [21].

- Wolves:

Wolves are very important in the ecosystem. They keep the prey animals in a healthy condition by choosing the oldest and weakest prey, they also keep space for different plants to grow.
It is also important for them to keep away from cities. We install a collar that fits the wolves and has a GPS signal that will give a shock if the wolves get closer to cities. The results of this will give less interaction between people and the wolves and also fewer road killings. The data we can get from the wolf's position will give us his living area.

- Effect of radioactive waste (in water):

Because of radioactive waste, the quality of water (especially in still water) is decreasing. Radioactive waste can kill fish in the water but is then also passed through the food chain. Cleaning this water takes years, after this we still have to slowly reintroduce this water into the environment. Even though many negative effects of radioactive water are known, we do not know the full effect it has on the environment.

Chapter 4: Problem Selection and Motivation

As mentioned in the previous chapters, many problems related to wildlife monitoring are mutually dependent. After discussing the feasibility of each problem and the associated difficulty and technological sophistication, we decided to focus on the problem of wolves. Before, we focused on frog tunnels and soil moisture content. The frog tunnel idea was a feasible idea from a hardware perspective, we noticed however, that no problem is solved when monitoring frogs as they are not threatened. Soil moisture is a big problem especially in light of climate change, and it affects a wide range of animals and plants. However, we came to the conclusion that soil moisture content is not feasible to tackle with the amount of resources at our disposal especially because a distributed network of sophisticated sensors is required to accurately monitor soil moisture. Finally, we settled on wolves as it is feasible and solves a pressing issue.

The wolfe is a keystone species for controlling certain populations of animals, as it has a direct and indirect impact on prey populations. Wolves keep grazers on the move which promotes the growth of small trees which normally would be eaten. Furthermore, leftover prey is a valuable food source for scavengers. These, among others, have a cascading effect down the food chain and enable stable growth of many other plants and animals.

Since the early 90’s, wolves are a protected species across europe and have re-populated areas in Eastern Europe, Germany and recently, the Netherlands. In October 2020, there were an estimated 105 wolf packs, 41 pairs, and 12 territorial individuals present in Germany [22].

Since the wolf was not present for the last 150 years, farmers and outdoor hikers are raising safety concerns about their livestock or pets. Wolves are highly specialized predators and regularly attack sheep and other livestock. This leads to some farmers taking rather drastic measures, for example, farmers in Friesland even campaigned for a 150 km long border fence to keep the wolves out of the area [23].

Nowadays, wolves seem to be more tame and therefore are coming closer to cities and farms, this of course, raises security concerns. To combat this, the Dutch government even allowed people to shoot wild wolves with paintball guns as an attempt to increase fear of humans. Although attacks from wolves against humans are rare, preventing wolves from entering certain areas might positively contribute to the public perception of the wolves. Since the presence of large predators in general is key for a stable environment, we humans need to be comfortable with the presence of them in our environment. Naturally, some will campaign against that. To reestablish the relationship between wolves and humans in modern day Europe, we decided to use technology to reduce friction between both parties, as the public perception of the wolf and whether or not it is ‘’welcome’’ in our society determines its ultimate survival.

The impact of the presence or absence of wolves as apex predators has huge ramifications for the environment as they serve as a natural regulator for many processes that occur in the wild. Furthermore, the human aspect is not to be underestimated in connection to this topic

since wolves in Europe have been largely eradicated by humans. Therefore, the public relations of the wolves are critical for ensuring a stable and flourishing presence of these animals in modern day europe. Many inhabitants of rural areas are afraid of the wolves, which further complicates the problem and has a negative impact on the public perception of the wolves.
Lastly, existing technologies on rather simple and cheap platforms, can serve as a great basis for detecting wolves in the wild. Most of which is within reach of our skills, which both enables us to work effectively and develop our skills further.

Chapter 5: Potential Solutions

In this Chapter, we present and evaluate different solutions to integrate wolves into modern society.

- App and a collar triggered by area:

Introduction: Wolves coming closer to crowded areas provokes danger for both animals and humans. A GPS collar that senses the location of a wolf can make a solution.
The collar is programmed to give a signal to the wolf when its location is too close to the unwanted areas(cities or dangerous roads). This signal could be a high frequency or a little shock to scare the wolf into changing direction. By programming the locations to avoid can be adjusted.
Advantages: the location is being constantly collected, that provides a great database that can potentially benefit in other wolf-related projects. It is animal friendly.
Drawbacks: the solution could be inconvenient for an animal. The product might not pass the WSPA* standards and raise questions about the ethical part of the project. Also wolves may habituate to noises so they do not get scared anymore by the noises.

- App and a collar triggered by forest wanderers:

Introduction: When taking a walk in the Hoge Veluwe smartphone makes a connection with the collar of the wolves and when it's in range the frequency a system activates.
Advantages: the location is being constantly collected, that provides a great database that can potentially benefit in other wolf-related projects. The creation of a smart system is great for promoting the solution.
Drawbacks: the solution could be inconvenient for an animal. The product might not pass the WSPA* standards and raise questions about the ethical part of the project. Additionally the connection might cause project limitations, as it would require either an inconvenient internet connection or an expensive satellite connection.

- Fence:

Introduction: The smart Fence detects if there is a wolf crossing. This results in the fence making an annoying noise that is being sensed and the wolf goes back into the woods away from the cities or roads.
Advantages: Most of the time the structure does not limit the life of the wolf. The noise does not harm an animal, that gives a chance to pass WSPA* standards. Additionally it can mark the territory for people as dangerous, if they would want to cross the barrier. Warning signs might lower the amount of people in the wolf habitat which would be in additional help in the project's mission of decreasing the tameness level of wolves.
Drawbacks: Because of similarities between wolves and dogs the sound can influence both species which might raise displeasure of dog owners. Dogs living nearby the fence area might develop serious health problems due to constant exposure to the noise.

- Wolf detection camera system:

Introduction: The detection camera system senses if there is a wolf in the area and detects it. Therefore the wolf goes back and runs away from the forbidden area.
Advantages: Camera photos build a great database that can be used in other wolf related projects.
Drawbacks: Since detecting is not enough that rises the need of a scaring solution that would pass WSPA* standards

- Bioacoustic Sound recognition system for wolves

Introduction: Recently, researchers at Nottingham Trent University have demonstrated 100% accuracy when using fundamental frequency and amplitude to identify wolf individuals[24]. This shows that using the simple technique is a viable way of identifying animals and even certain individuals using relatively simple equipment. It is to note however, that the above mentioned effects have been demonstrated in a controlled captive environment, it leads to believe that there real use case in wild environments.
Due to the nature of a controlled environment, the above mentioned researchers were able to collect high quality howls with minimum background noise. To mitigate this in the wild, a high quality microphone has to be set up in order to catch the howls with enough details for further research. This can be used to identify individuals location, and movement patterns, as well as other behavioral changes that are connected to a wolves howl.
Advantages: Relatively low tech, unobtrusive.
Drawbacks: Analysis algorithm has to be somewhat sophisticated in order to filter out noise and identify individuals correctly. High-power consumption due to constant listening.

*WSPA- The World Society for the Protection of Animals

Chapter 6: Solution Selection

After a discussion the group decided to develop a smart-collar that transmits the location of wolves. There are lots of opportunities for putting different sensors in the collar, depending on cost, power usage and feasibility, further research has to be done to determine which sensors are fitting in this use case.

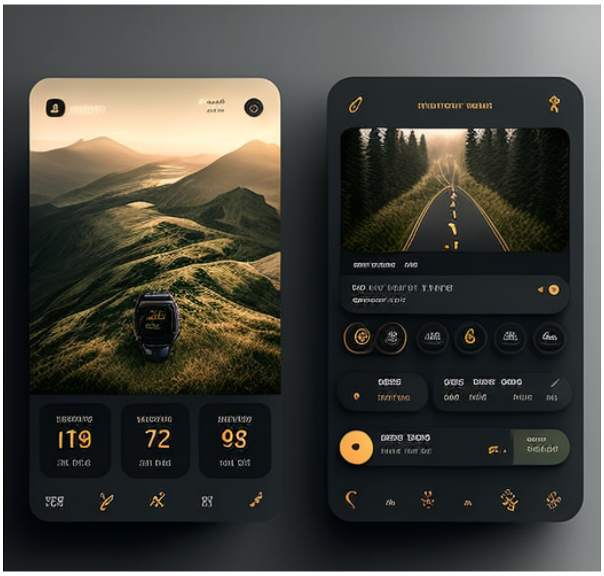
Additionally, we aim for the most unobtrusive solution as we believe that less human interaction into the environment is a generally good thing. Collars are generally believed to be safe for dogs as long as no excessive force is applied. Since we are using the collar as a means to attach sensory equipment to a wolf, we can omit these harms for a wolf, granted the design of the encasing for the sensors is not irritating to the wolf.
There is an advantage to the device being tested on the wolf itself, less resources are required to monitor it. If you were to use a static monitoring device like the fence, the device needs to be in a lot of places to be accurate and helpful, which increases cost and reduces convenience. Furthermore, Wolves can travel large distances, which makes fences quite inefficient. By having the collar on the wolf, the data will also be more accurate, as it is derived from close proximity to the wolf. The collar is the most feasible idea taking into consideration the skills of all group members.

Using an Arduino Leonardo, and a connected GPS module and transmitter. Prototyping such a collar with a suitable encasing will be developed during this project.
Our goal is to develop a smart environment within the overarching theme of wildlife monitoring. Smart environments are applications of ubiquitous computing (UC). After the rise of integrated circuits in the late 20th century, computer chips and their applications are made available on ever more efficient and powerful platforms. This gave rise to the idea of UC, which essentially describes the availability of computer-based services in ever more situations and environments, using any device in any location using any format The idea has been developed at the famous Xerox PARC laboratory where many principles and groundbreaking ideas of modern computing have been founded. Mark Weiser, one of the executives at Xerox PARC coined the term UC and later additions identified five aspects of UC. For systems to be identified as UC, they have to be *Autonomous, Distributed, Context Aware, Intelligent*, and offers *Implicit Interaction*.
For UC systems to be autonomous, they have to be able to operate without constant human interaction, be self-governed and independent. Distributed UC systems have to be connected into a network in order to send and receive data, and distributed across multiple locations and connections. Furthermore, context awareness is achieved if UC systems are sensing, adapting and/or controlling their
environment, and demonstrate the ability to show relevant information to users according to a specific context. Intelligent UC Systems are goal based and have the innate ability to handle non-deterministic situations. Implicit Interaction alludes to the user friendliness of the UC

System and the design of the system to communicate an implicit interaction protocol to its user, hiding the technical aspects of the computer and its connected elements in the background. The wolf collar is an example of a Smart environment, since it demonstrates all of the aspects of UC. The collar is an autonomous sensing system that is able to send positional data via its GPS module without human- interaction. The aspect of autonomy has to be emphasized in this project, since wolves are wild animals that are constantly on the move which makes human interaction with the device difficult.

The collar will be a distributed system since the data can be accessed locally and remotely. Furthermore, the collar will be based on different layers featuring a hardware layer: the Arduino, GPS module, transmitter, receiver, and power supply, a middle layer: the Arduino code and its "operating system", and a human-computer interaction at the top: UI, Heatmaps, Smartphone application etc.
The design of the collar allows minimal disturbance of the wolf and enables it to live a normal life without suffering any consequences or downsides. The open nature of the Arduino allows later implementation of features and constant reiteration of the collar and its features.
The collar features Human-computer interaction only at the software level, which makes the device itself invisible to the human eye.
The collar is context-aware, since it has different modes of operation according to the area the wolf is at. The idea of heatmaps is serving as an important distinction between areas where the wolf is tolerated, and where it is not.

Collar and application ideation:



Tasks division:

- Purchasing hardware
- 3d model creation
- Slicing
- Soldering
- Programming Arduino
- Installation
- Leading design department
- Mock up of the dashboards for heatmaps
- Validation
- Final presentation and marketing
- Documentation

Name of student	Area of expertise	Project tasks
Sebastian Orgel	Leadership	Validation **Final presentation/marketing** Programming Arduino
David de Groot	Software	Validation **3d modeling** Programming processing
Rares Ioan-Ionescu	Hardware	Validation **Programming Arduino** **Installation** **Purchasing hardware**
Sylvia Zhao	Design	Validation **Programming arduino**
Ewoud Janus	Design	Validation 3d modeling **Programming processing**
Fleur Groot Nibbelink	Documentation	Validation 3d modeling **Documentation**
Ekaterina Koshkina	Design	Validation Mock up of the dashboards **Leading design department**
Theo van den Berg	Software	Validation Installation **Documentation**

(Bold tasks: main responsibility)

Chapter 7: Methodology

In this Chapter, the Methodology of our approach will be introduced and further explanation is provided into how WolfRadar is helping to integrate wolves into modern society. Furthermore, technical concerns and details as well as data collection and verification will be discussed.

Since our goal is to reintroduce the wolf into modern society, public perception of the wolf is crucial to ensure humans and wolves can coexist. Therefore, we want to demarcate certain areas: farms, schools, popular hiking spots etc. in which wolf-human interactions are likely and/or can cause financial harm. If these areas are approached, the collar increases the rate of data transmission, therefore enabling local authorities, hikers, and farmers a more accurate tracking of wolves allowing for better protection and preventative measures. Traditionally, a lot of processing power and local storage would be required for the module to know where it is on the map and where these designated areas are. Another Arduino module is attached to a computer to serve as the transceiver between the collar and the computer, the Arduino is receiving the GPS coordinates, and is able to tell the Arduino to increase/ decrease its transmission frequency in specified areas. Basically, it serves as a remote control between the collar and processing/ user interface.

<u>Sensors and Connections</u>
To find the actual location of the wolves and transmit the data, the following items have been used to design a circuit that is able to transmit a GPS location and receive instructions.

- GPS Module GY-NEO6MV2
- 2x Arduino Uno
- 2x XBee module
- Atlas Scientific 8:1 Serial Port expander

<u>Installation of collars and test projects</u>
The installation of the collars is a big challenge. Wolves are wild animals and can be dangerous when they feel threatened. To test the collars on full grown Wolves, Wolf Research Centers can offer the expertise with handling these animals.
There are only a few research centers dedicated to studying wolves, one promising research center is the Wolf Science Center in Austria, a cooperation with a wildlife park and the University of Veterinary Medicine Vienna dedicated to studying the behavior and conservation of wolves[25]. The researchers provide the expertise to handle the installation of the collars, and whether or not an anesthetic has to be used.
Although the Geography is quite different from the Netherlands, Austria is a popular location for hikers and skiers. Therefore, the public opinion towards wolves also depends on recent attacks.

<u>Data collection and Analysis</u>
In this section, the data collection, analysis and validity of our results will be elaborated. Since our wolf collar is supposed to be used in the wild, we are facing several challenges such as: dirt, humidity, the weather, etc. Although wolves do not live in a controlled environment,

it is not expected to alter our data significantly. The changes in the wolves behavior due to its environment are also the things we want to monitor.
When we field-test our prototype we are going to test our collar in a more controlled environment. Instead of testing the collar on a wild animal, testing the collar on a dog would give the closest resemblance to a wolf since dogs are closely related to wolves and closely resemble body movements and overall body structure.
A special casing is needed for the collar to withstand water and possible damages due to movement, as well as ensuring the proper functioning of the internal sensors. This encasing is supposed to be designed in such a way that enables comfortable carrying of the components and enables minimal disturbance in daily life.

Data

After calibrating the sensor, by taking an initial sample and comparing that to a reference, we can determine how accurate the GPS signal is.
We collect the location of the wolf via a GPS logger shield and send it once per day. If wolves enter an area we don't want them to enter, the data is sent more often, to allow better location and intervention/prevention. This is achieved by using a processing sketch that has a map and certain areas that are marked as impermissible. If a signal is located in one of these areas, Processing is sending a signal to the transceiver Arduino to send a signal to the collar to increase transmission frequency.
The data can be used by researchers to research behavioral patterns of wolves, or determine areas that are frequently visited by wolves. By researching this, people can take action and for example make other areas more attractive for wolves. By looking at the heat map of frequently visited areas we can also send a message to for example foresters nearby, so that they can take action in chasing the wolf away, or warn nearby people that walk in the forest.

Validation

First, the necessary features will be discussed, furthermore, the testing methodology and validity of results will be discussed. Lastly, an ambitious plan explains how we aim to further improve the overall quality and impact of our system and how this is achieved.
The validity of our results depends on the following objectives and success criteria:

- The collar should be able to track the wolf's location and transmit the data to a receiver.
- Data sampling should be adaptive to preserve battery life.
- Data should be readable and clearly show the wolf’s location.
- The collar should be fastened well and not fall off during testing, stay intact and be sturdy enough to withstand rainy weather and be protected against dirt.
- Make sure there is no hazard for the wolf while wearing the collar.
- A still satellite picture with adaptive proximity recognition zones.

We also want to test the durability and water resistance of the collar. This will be done as a field test near the University of Twente.

Problem Solution

Since our goal is to reintroduce the wolf into modern society, public perception of the wolf is important to ensure humans and wolves can coexist. Demarcating certain areas: farms, schools, popular hiking spots etc. in which wolf-human interactions are likely and/or can cause financial harm is an important goal to achieve accurate control of wolves.

The wolf collar will help expand our knowledge about wolves, specifically their location. Our data can give more information about their preferred habitat. This information can be used to create better environments to enlarge their habitat. Whichever way we use our data, we can make sure wolves and humans can live side by side. The most important aspect to consider is the public perception of the wolf and its dangers to farm animals and humans.

As alluded to earlier, the danger of a wolf attack is very low as wolves usually don't prey on humans, however, enabling a more accurate monitoring of wolves and their behavior allows us to reconcile points of friction between humans and wolves, such as enabling farmer to defend their farms more efficiently, as well as alarming authorities when wolves approach schools for example. To prevent people other than authorities from abusing this service and knowing where the wolf is all the time, we only send data to for example farmers when the wolf is close to the farm (using the earlier mentioned proximity zones). All this enables us to prevent the public falling out with the wolf and the dramatic consequences the wolf suffered when it was eradicated some 150 years ago. The data collected can be used for public education about the wolf and its importance in the food chain.

To achieve a favorable public opinion towards the wolf, an information campaign advertising theWolfRadar should aim at raising awareness and present a coherent argument for:

1. Why Wolves are important to the Environment and which function they serve in the environment.
2. Advertise the use of the WolfRadar in order to feel safe and prevent serious harm and/or damage.
3. Providing a call-to-action and enabling easy participation in the project.

Beyond that, the WolfRadar app and website should aim to:

- clearly demonstrate how technology can be used to educate people.
- Provide a pleasant User Interface and educational material

Ambitious plan

In this chapter, we are describing how an advanced version of the WolfRadar looks and what features it has. Same as in the “basic scenario” public perception of the wolf is crucial. Enhancing the human-animal connection and educating the society about the impact of wolves further is achieved by providing applications on multiple platforms and catered towards multiple stakeholders. A general portal for the public serves as an information gateway to know if wolves are in the vicinity, and how different wolf packs flourish and what impact they have on the environment.

Furthermore, a government specific portal can be used for government agencies, conservationists and policemen to have access to the raw data and movement patterns of the wolves such that experts can stay informed and make use of the data, and that police can investigate and/or prevent attacks.

Receiving more information about wolves' behavior will increase understanding and make way for possible more interventions between wolves and people.

Adding different sensors to the collar is a possible way to increase the understanding of a wolf's behavior. For example, introducing a heart rate sensor into the collar will give information about heart problems and the possibility to treat irregularities. Also, a heart rate gives us an indication of the condition of the wolves.
With an accelerometer, we can determine how active a wolf is. Further creating ways to determine health and possible activity of the wolves. This, of course, has a high impact on the energy consumption of the collar and has to be taken into account.

With long term usage of the collars, patterns in grouping of animals can be found. Not only will it give information about where wolves populate, but also with how many. This will lead to knowing packs of wolves and possible new births to check on.
When walking paths of wolves cross those of humans, restrictions to walking paths can be implemented to let humans and wolves live with each other without too much interaction. Big data gives the opportunity to study patterns in the wolves' location. The behavior of wolves, migration patterns and population estimates can be studied. Additionally, the information gathered could be used to inform strategies for managing the population of the wolves and their interaction with humans.

The wolf collar is very durable and able to withstand harsh weather conditions as well as rough handling of the wolf. To reduce the need for check ups and charging of the collar, the energy source is self-sustainable. Considering the placement of the collar and the movement of the wolves, the energy will be generated by kinetic energy.

To increase the durability of the collar even more, a consideration could be made to switch to a more solid and unbreakable material than 3d printed plastic. Implementing this improvement will make maintenance checks less common. Materials that could be used would be carbon fiber, metal, silicone and more. Preferably a material will be chosen that would be non-toxic to the wolves if they decide to try and destroy the collar.

Timeplan

16 Dec.	Adding chapter 0 (introduction) Adding chapter 7. How does my solution qualify as a smart environment? ● Theo Which equipment to use? Would the sensor need calibration? ● Rares ● Sylvia Would the equipment be used in a controlled environment or not? In the latter, would a special casing be needed? ● Fleur ● David ● Kate How to collect data? When to collect it? How to analyze data? How to use data for automation/control/actuation? Validation? ● David ● Rares ● Sylvia ● Ewoud ● Fleur How does my methodology lead to a solution that solves the problem under study? ● Theo

20 Dec.	During the lecture we start with the following tasks. Designing the collar: David, Ewoud and Fleur Slicing the designed 3d models for the 3d printer: Ewoud Programming for the installation: Rares, David, Sylvia, Theo and Sebastian Mock up of dashboards: Kate and Fleur
22 Dec.	Chapter 0 introduction: Theo, Ewoud, David, Rares, Sylvia and Fleur
6 Jan.	When we achieve the hardware assignment faster we can start measuring the 10th of January.
10 Jan.	Consider how to test/validate our solution. Slicing the designed 3d models for the 3d printer: Ewoud Soldering the hardware together: Sylvia and Fleur Programming: Rares, David, Sylvia and Sebastian Finishing the mock up of dashboards: Kate and Fleur
17 Jan.	Consider how to test/validate our solution. Slicing the designed 3d models for the 3d printer: Ewoud Soldering the hardware together: Sylvia and Fleur Programming: Rares, David, Sylvia and Sebastian Finishing the mock up of dashboards: Kate and Fleur Testing the prototype.

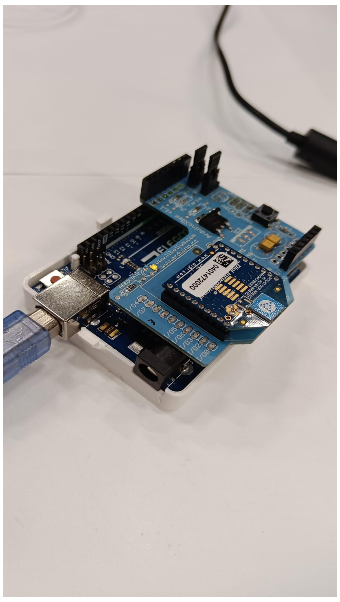
20 Jan.	Testing the final product: everybody Viewing the results in the dashboards : Kate and Fleur Validating results. Adding results to our document together with findings and conclusions. Adding results to the document: Sylvia and Theo Adding findings and conclusions to the document: everybody
24-27 Jan	Demonstration to the public. Archiving our project to the Creative Archive. Giving the presentation and demonstration: Sebastian and Ewoud

Chapter 8: Validation

During this chapter, the validation of the WolfRadar prototype will be discussed.
Over the past couple of weeks, the WolfRadar prototype has been in active development and is ready for testing and validation. The proof-of-concept prototype features two modules, one module that is attached to the wolf, and one that is attached to a computer which is able to receive data. We aimed at a device that can send the coordinates as well as receive instructions for modifying the transmission frequency to save energy. This, however, did not come to fruition and we were not able to implement a working version.
We aim to demonstrate the feasibility of the WolfRadar and show that the electrical components work and that the desired data can be obtained.
In addition to demonstrating that the hardware and software is working, the encasing has to be rigid and able to withstand certain weather conditions.
The ultimate goal of the WolfRadar is changing the public's perception of wolves. Creating a questionnaire will test this perception in a before-after comparison. The questionnaire will include questions about their views on wolves before and after showing the WolfRadar and an explanatory video.
Based on the outcome of that survey we can determine whether or not there has been a positive effect on the perception of wolves. Although not statistically significant, it can serve as an important indicator for future pilot-studies and serve as a platform for researchers and conservationists.

To validate the electrical components and software, we attached the collar to a small dog to simulate how the collar is worn by a comparable animal. During our testing we were successful in receiving the GPS position of the collar. This data has been used by processing to create a heatmap of the different spots and work as a reference map for prevention measures.
The encasing itself has been tested by first attaching it to the dog and letting the dog roam free, and secondly, by spraying water on the encasing and checking whether moisture entered.

Chapter 9: Results and Conclusion



The development of the GPS collar has been successful, the features have been tested in a field trial. The collar was able to accurately track the location and transmit the data to a receiver module. A computer attached to the receiver module was able to receive the GPS data and use it to paint a heatmap of the location.
Originally, we planned to adapt the sensing rate to the environment and make the collar context-aware. Hardware limitations on the Arduino did not allow for a map to be stored on the Arduino, we planned to use another XBee module for sending data from the receiver to the collar to adjust the transmission rate, however, we failed to achieve that.
The online survey is a tool for demonstrating the possible impact such a platform can have on the perception of Wolves and raise interest in their conservation.
We proved that a relatively simple device can change people's perception of dangerous animals and that wildlife monitoring in the case of wolves is feasible and can serve as grounds for a new human-wolves relationship.
The results of the online survey showed that the information provided on the website and the video showing the product and its features positively benefited the perception of wolves. More people are aware of the benefits of wolves and less scared of possible interaction. Furthermore, the general interest in Wolves has increased, which is a secondary goal, but which cannot be understated.
Regarding the encasing, we managed to print an encasing that is reasonable in size and can fit onto a Wolfe. It is sturdy and can withhold dirt, it is not watertight however. This has to be addressed in future prototypes.
All in all, the repopulation of Wolves can be greatly supported by using modern technology. This can enhance the wolves potential to serve its role in the ecosystem and meanwhile reduce its perceived threat by preventing serious harm to humans and livestock alike. This can greatly increase the public interest in Wolves which is also beneficial for Wolves.

GPS Collar (Antenna, Arduino, Power Supply)

Bibliography

[1] T. Huijsmans, “Wildlife research in the south of the Netherlands,” Faunawatch, 28-Sep-2022. [Online]. Available: https://www.faunawatch.org/wildlife-research-in-the-south-of-the-netherlands [Accessed: 18-Nov-2022].

[2] Y. Fiesting, P. A. Jansen, and J. den Ouden, publication, “A wildlife monitoring network for De Hoge Veluwe National Park”, Nov 2012. Available: https://www.hogeveluwe.nl/files/A_wildlife_monitoring_network_for_De_Hoge_Veluwe_National_Park.pdf

[3] Digital Beekeeping (no date) BEEP. Beep company. Available at: https://beep.nl/index.php/home-english (Accessed: November 21, 2022).

[4] Marcot, B.G.; Vander Heyden, M. Key ecological functions of wildlife species. In Wildlife-Habitat Relationships in Oregon and Washington; Johnson, D.H., O'Neil, T.A., Eds.; Technical Coordinators Oregon State University Press: Corvallis, OR, USA, 2001. (PDF) Key Ecological Functions of Wildlife Species (researchgate.net)

[5]“Threats to Wildlife,” National Wildlife Federation. http://nwf.org/Educational-Resources/Wildlife-Guide/Threats-to-Wildlife (accessed Nov. 22, 2022).

[6]A. L. W. Schwartz, F. M. Shilling, and S. E. Perkins, “The value of monitoring wildlife roadkill,” European Journal of Wildlife Research, vol. 66, no. 1, Jan. 2020, doi: 10.1007/s10344-019-1357-4.

[7]V. Trifa, L. Girod, T. C. Collier, D. Blumstein, and C. E. Taylor, “Automated Wildlife Monitoring Using Self-Configuring Sensor Networks Deployed in Natural Habitats,” escholarship.org, 2007, Accessed: Nov. 21, 2022. [Online]. Available: https://escholarship.org/uc/item/2059b99k

[8] C. P. Cordier, D. A. Ehlers Smith, Y. Ehlers Smith, and C. T. Downs, “Camera trap research in Africa: A systematic review to show trends in wildlife monitoring and its value as a research tool,” Global Ecology and Conservation, vol. 40, p. e02326, Dec. 2022, doi: 10.1016/j.gecco.2022.e02326.

[9] C. M. Wood, R. J. Gutiérrez, and M. Z. Peery, “Acoustic monitoring reveals a diverse forest owl community, illustrating its potential for basic and Applied Ecology,” Ecology, vol. 100, no. 9, pp. 1–3, 2019.

[10] J. M. Wilmshurst and J. K. Carpenter, “Rodent detection and monitoring for conservation on islands: Gnawed seeds provide reliable indicator of rodent presence,” New Zealand Journal of Ecology, vol. 44, no. 1, pp. 1–9, 2020.

[11] J. C. Hodgson, R. Mott, S. M. Baylis, T. T. Pham, S. Wotherspoon, A. D. Kilpatrick, R. Raja Segaran, I. Reid, A. Terauds, and L. P. Koh, “Drones count wildlife more accurately and precisely than humans,” Methods in Ecology and Evolution, vol. 9, no. 5, pp. 1160–1167, 2018.

[12] Burton, A.C. (2012) Critical evaluation of a long-term, locally-based wildlife monitoring program in West Africa - Biodiversity and conservation, SpringerLink. Springer Netherlands. Available at: https://link.springer.com/article/10.1007/s10531-012-0355-6#Sec7

[13] W. G. Meikle and N. Holst, “Application of continuous monitoring of honeybee colonies ,” SpringerLink, 27-Jun-2014. [Online]. Available: https://link.springer.com/article/10.1007/s13592-014-0298-x#citeas. [Accessed: 21-Nov-2022].

[14] E. L. Clare et al., “Measuring biodiversity from DNA in the air,” Current Biology, Jan. 2022, doi: 10.1016/j.cub.2021.11.064.

[15] E. Banchi et al., “Environmental DNA assessment of airborne plant and fungal seasonal diversity,” Science of The Total Environment, vol. 738, p. 140249, Oct. 2020, doi: 10.1016/j.scitotenv.2020.140249.

[16] The Society for Conservation Biology (no date). Available at: https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/csp2.568 (Accessed: November 21, 2022)

[17] Gonzalez, L.F. et al. (2016) Unmanned Aerial Vehicles (uavs) and artificial intelligence revolutionizing wildlife monitoring and conservation, MDPI. Multidisciplinary Digital Publishing Institute. Available at: https://www.mdpi.com/1424-8220/16/1/97 (Accessed: November 21, 2022).

[18] J. P. Dominguez-Morales, L. Duran-Lopez, D. Gutierrez-Galan, A. Rios-Navarro, A. Linares-Barranco, and A. Jimenez-Fernandez, “Wildlife Monitoring on the Edge: A Performance Evaluation of Embedded Neural Networks on Microcontrollers for Animal Behavior Classification,” Sensors, vol. 21, no. 9, p. 2975, Apr. 2021, doi: 10.3390/s21092975.

[19] H. Nguyen et al., "Animal Recognition and Identification with Deep Convolutional Neural Networks for Automated Wildlife Monitoring," 2017 IEEE International Conference on Data Science and Advanced Analytics (DSAA), 2017, pp. 40-49, doi: 10.1109/DSAA.2017.31.

[20] Xiaohan Liu, Tao Yang and Baoping Yan, "Internet of Things for wildlife monitoring," 2015 IEEE/CIC International Conference on Communications in China - Workshops (CIC/ICCC), 2015, pp. 62-66, doi: 10.1109/ICCChinaW.2015.7961581.

[21] European Environmental Agency, *Soil moisture deficit*, 18-Nov-2021. [Online]. Available: https://www.eea.europa.eu/ims/soil-moisture-deficit. [Accessed: 28-Nov-2022].

[22] “Über uns,” *Gesellschaft zum Schutz der Wölfe E.V.* [Online]. Available: https://www.gzsdw.de/ueber_uns. [Accessed: 08-Dec-2022].

[23] robin, “Frisian farmers campaign for border fence to keep out wolves,” *DutchNews.nl*, Jan. 07, 2021. https://www.dutchnews.nl/news/2021/01/frisian-farmers-campaign-for-border-fence-to-keep-out-wolves/ (accessed Dec. 08, 2022).

[24] H. Root-Gutteridge *et al.*, “Identifying individual wild Eastern grey wolves (Canis lupus lycaon) using fundamental frequency and amplitude of howls,” *Bioacoustics*, vol. 23, no. 1, pp. 55–66, Jul. 2013, doi: 10.1080/09524622.2013.817317.

[25] https://www.wolfscience.at/en/

Appendix:

Questionnaire:

There are 12 questions in total each being rated by a Likert scale from Strongly agree to Strongly disagree.

Wolves are dangerous animals

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

I do not care about Wolves and how they impact the environment.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Wolves provide important benefits for the ecosystem.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Wolves pose no threat to humans.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Technology is useful when dealing with dangerous animals.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Wolves and humans can live alongside each other.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Wildlife monitoring can be used to reduce dangerous encounters with Wolves.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Wolves do not serve any useful function in the environment.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Wolves and humans cannot live in the same territory as it is too dangerous for both.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Wildlife monitoring cannot serve to reduce dangerous encounters with animals.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Applied technology is not useful when dealing with dangerous animals.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

I care about Wolves and their impact on nature.

Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
○	○	○	○	○

Questionnaire Results

Q1 - Wolves are dangerous animals

#	Field	Minimum	Maximum	Mean	Std Deviati	Variance	Count
1	Wolves are	1	5	2.61	1.16	1.33	31

#	Answer	%	Count
1	Strongly ag	12.90%	4
2	Agree	45.16%	14
3	Neither agr	19.35%	6
4	Disagree	12.90%	4
5	Strongly di	9.68%	3
	Total	100%	31

Q2 - I do not care about Wolves and how they impact the environment.

#	Field	Minimum	Maximum	Mean	Std Deviati	Variance	Count
1	I do not car	1	5	3.45	1.32	1.73	31

#	Answer	%	Count
1	Strongly ag	12.90%	4
2	Agree	9.68%	3
3	Neither agr	22.58%	7
4	Disagree	29.03%	9
5	Strongly di	25.81%	8
	Total	100%	31

Q3 - Wolves provide important benefits for the ecosystem.

#	Field	Minimum	Maximum	Mean	Std Deviati	Variance	Count
1	Wolves prc	1	5	2.06	0.95	0.9	31

#	Answer	%	Count
1	Strongly ag	29.03%	9
2	Agree	45.16%	14
3	Neither agr	19.35%	6
4	Disagree	3.23%	1
5	Strongly di	3.23%	1
	Total	100%	31

Q4 - Wolves pose no threat to humans.

#	Field	Minimum	Maximum	Mean	Std Deviati	Variance	Count
1	Wolves pos	1	5	2.97	1.06	1.13	31

#	Answer	%	Count
1	Strongly ag	9.68%	3
2	Agree	22.58%	7
3	Neither agr	35.48%	11
4	Disagree	25.81%	8
5	Strongly di	6.45%	2
	Total	100%	31

Q5 - Technology is useful when dealing with dangerous animals.

#	Field	Minimum	Maximum	Mean	Std Deviati	Variance	Count
1	Technolog	1	5	2	0.98	0.97	31

#	Answer	%	Count
1	Strongly ag	32.26%	10
2	Agree	48.39%	15
3	Neither agr	9.68%	3
4	Disagree	6.45%	2
5	Strongly di	3.23%	1
	Total	100%	31

Q6 - Wolves and humans can live alongside each other.

#	Field	Minimum	Maximum	Mean	Std Deviati	Variance	Count
1	Wolves anc	1	5	2.37	1.2	1.43	30

#	Answer	%	Count
1	Strongly ag	26.67%	8
2	Agree	36.67%	11
3	Neither agr	16.67%	5
4	Disagree	13.33%	4
5	Strongly di	6.67%	2
	Total	100%	30

Q13 - Wolves are dangerous animals

#	Field	Minimum	Maximum	Mean	Std Deviati	Variance	Count
1	Wolves are	1	5	2.96	1.29	1.65	26

#	Answer	%	Count
1	Strongly ag	11.54%	3
2	Agree	34.62%	9
3	Neither agr	15.38%	4
4	Disagree	23.08%	6
5	Strongly di	15.38%	4
	Total	100%	26

Q14 - I do not care about Wolves and how they impact the environment.

#	Field	Minimum	Maximum	Mean	Std Deviati	Variance	Count
1	I do not car	2	5	4.04	0.85	0.73	26

#	Answer	%	Count
1	Strongly ag	0.00%	0
2	Agree	7.69%	2
3	Neither agr	11.54%	3
4	Disagree	50.00%	13
5	Strongly di	30.77%	8
	Total	100%	26

Q15 - Wolves provide important benefits for the ecosystem.

#	Field	Minimum	Maximum	Mean	Std Deviati	Variance	Count
1	Wolves prc	1	5	1.96	0.98	0.96	26

#	Answer	%	Count
1	Strongly ag	34.62%	9
2	Agree	46.15%	12
3	Neither agr	11.54%	3
4	Disagree	3.85%	1
5	Strongly di	3.85%	1
	Total	100%	26

Q16 - Wolves pose no threat to humans.

#	Field	Minimum	Maximum	Mean	Std Deviati	Variance	Count
1	Wolves pos	1	5	2.85	1.17	1.36	26

#	Answer	%	Count
1	Strongly ag	7.69%	2
2	Agree	42.31%	11
3	Neither agr	19.23%	5
4	Disagree	19.23%	5
5	Strongly di	11.54%	3
	Total	100%	26

Q17 - Technology is useful when dealing with dangerous animals.

#	Field	Minimum	Maximum	Mean	Std Deviati	Variance	Count
1	Technolog	1	4	1.88	0.8	0.64	26

#	Answer	%	Count
1	Strongly ag	34.62%	9
2	Agree	46.15%	12
3	Neither agr	15.38%	4
4	Disagree	3.85%	1
5	Strongly di	0.00%	0
	Total	100%	26

Q18 - Wolves and humans can live alongside each other.

#	Field	Minimum	Maximum	Mean	Std Deviati	Variance	Count
1	Wolves anc	1	5	2.12	0.93	0.87	26

#	Answer	%	Count
1	Strongly ag	23.08%	6
2	Agree	53.85%	14
3	Neither agr	15.38%	4
4	Disagree	3.85%	1
5	Strongly di	3.85%	1
	Total	100%	26

Q7 - Wildlife monitoring can be used to reduce dangerous encounters with Wolves.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wildlife mon	1	4	1.87	0.79	0.63	31

#	Answer	%	Count
1	Strongly agre	32.26%	10
2	Agree	54.84%	17
3	Neither agre	6.45%	2
4	Disagree	6.45%	2
5	Strongly disa	0.00%	0
	Total	100%	31

Q8 - Wolves do not serve any useful function in the environment.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wolves do nc	1	5	4.06	1.19	1.42	31

#	Answer	%	Count
1	Strongly agre	6.45%	2
2	Agree	6.45%	2
3	Neither agre	9.68%	3
4	Disagree	29.03%	9
5	Strongly disa	48.39%	15
	Total	100%	31

Q9 - Wolves and humans cannot live in the same territory as it is too dangerous for both.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wolves and h	1	5	3.3	1.16	1.34	30

#	Answer	%	Count
1	Strongly agre	6.67%	2
2	Agree	20.00%	6
3	Neither agre	26.67%	8
4	Disagree	30.00%	9
5	Strongly disa	16.67%	5
	Total	100%	30

Q10 - Wildlife monitoring cannot serve to reduce dangerous encounters with animals.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wildlife mon	1	5	3.84	0.95	0.91	31

#	Answer	%	Count
1	Strongly agre	3.23%	1
2	Agree	6.45%	2
3	Neither agre	16.13%	5
4	Disagree	51.61%	16
5	Strongly disa	22.58%	7
	Total	100%	31

Q11 - Applied technology is not useful when dealing with dangerous animals.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Applied techi	2	5	3.87	0.83	0.69	31

#	Answer	%	Count
1	Strongly agre	0.00%	0
2	Agree	9.68%	3
3	Neither agre	12.90%	4
4	Disagree	58.06%	18
5	Strongly disa	19.35%	6
	Total	100%	31

Q12 - I care about Wolves and their impact on nature.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	I care about V	1	5	2.19	1.09	1.19	31

#	Answer	%	Count
1	Strongly agre	29.03%	9
2	Agree	41.94%	13
3	Neither agre	12.90%	4
4	Disagree	12.90%	4
5	Strongly disa	3.23%	1
	Total	100%	31

Q19 - Wildlife monitoring can be used to reduce dangerous encounters with Wolves.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wildlife mon	1	4	1.77	0.85	0.72	26

#	Answer	%	Count
1	Strongly agre	46.15%	12
2	Agree	34.62%	9
3	Neither agre	15.38%	4
4	Disagree	3.85%	1
5	Strongly disa	0.00%	0
	Total	100%	26

Q20 - Wolves do not serve any useful function in the environment.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wolves do nc	1	5	4	1.07	1.15	26

#	Answer	%	Count
1	Strongly agre	3.85%	1
2	Agree	7.69%	2
3	Neither agre	11.54%	3
4	Disagree	38.46%	10
5	Strongly disa	38.46%	10
	Total	100%	26

Q21 - Wolves and humans cannot live in the same territory as it is too dangerous for both.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wolves and h	1	5	3.92	1	0.99	26

#	Answer	%	Count
1	Strongly agre	3.85%	1
2	Agree	3.85%	1
3	Neither agre	19.23%	5
4	Disagree	42.31%	11
5	Strongly disa	30.77%	8
	Total	100%	26

Q22 - Wildlife monitoring cannot serve to reduce dangerous encounters with animals.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Wildlife mon	2	5	3.96	0.87	0.76	25

#	Answer	%	Count
1	Strongly agre	0.00%	0
2	Agree	8.00%	2
3	Neither agre	16.00%	4
4	Disagree	48.00%	12
5	Strongly disa	28.00%	7
	Total	100%	25

Q23 - Applied technology is not useful when dealing with dangerous animals.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Applied techi	2	5	3.96	0.85	0.73	26

#	Answer	%	Count
1	Strongly agre	0.00%	0
2	Agree	7.69%	2
3	Neither agre	15.38%	4
4	Disagree	50.00%	13
5	Strongly disa	26.92%	7
	Total	100%	26

Q24 - I care about Wolves and their impact on nature.

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	I care about V	1	5	1.96	1.09	1.19	26

#	Answer	%	Count
1	Strongly agre	38.46%	10
2	Agree	42.31%	11
3	Neither agre	11.54%	3
4	Disagree	0.00%	0
5	Strongly disa	7.69%	2
	Total	100%	26