research report ver 20

PROJECT APPLICATION DEVELOPMENT - InHolland University of Applied Science

Abstract

This research report explores the development of an application that results from a possible solution, to a problem taken from an existing ecological system, by using a mathematical model to show the predicted effects of the proposed measure on the ecosystem.

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Table of Contents

[1. Introduction 2](#_Toc471671397)

[1.1. Context 2](#_Toc471671398)

[1.2. Purpose 2](#_Toc471671399)

[2. Central research question and sub-questions 2](#_Toc471671400)

[2.1. Research question 2](#_Toc471671401)

[2.2. Research sub-questions 3](#_Toc471671402)

[3. Research Methodology 3](#_Toc471671403)

[4. Results 9](#_Toc471671404)

[5. Conclusion 9](#_Toc471671405)

[6. Recommendations 9](#_Toc471671406)

[7. Bibliographies 10](#_Toc471671407)

[8. Appendices 11](#_Toc471671408)

[8.1 Calculations 11](#_Toc471671409)

[8.2 Dietary distribution in percentages. 12](#_Toc471671410)

[8.3 Competition Coefficient Calculations 13](#_Toc471671411)

[8.4 Assumptions 15](#_Toc471671412)

[8.5 UML Diagrams 16](#_Toc471671413)

# Introduction

Mathematical engineering is based on developing application models for making predictions and find desirable solutions to real-life problematic situations. While working towards the development of an application, one comes across several challenges which fluctuate the approach of development. Challenges can be encountered when determining the model of the application, due to the observation and collection of data which is relevant to use as variables in a mathematical formula. Thus, parameters are going to be divided into categories, such as the essential and trivial factors, then later implemented to improve the model. Therefore, due to the level of complexity, that the model may hold, it is mandatory to not only implement an application which gives an output statistical numbers but visuals as well, such as graphs.

## 1.1 Context

Oostvaardersplassen, a preserved ecological system, which has many animals living there including the main three large herbivores: wild horses, wild cattle, and deer; and other foremost species such as geese and birds of prey. Conjecting that no major predators are present in the ecological system and the herbivores prohibited migration, unbalance has been settled in the Oostvaardersplassen preservation.

Complicating the situation is the fact that there are a lot of geese, particularly during winter, and they consume the same type of food as the large herbivores do. The competition and interaction between the herbivores and the geese for food can be quite severe, leading some to extreme situations such as death.

## 1.2 Purpose

The purpose of this project is to work towards a possible solution of a problem taken from an existing ecological system, Oostvaardersplassen. Based on a mathematical model the system for the application will be the one doing the number crunching. This will then result in a graphical illustration of the predicted effects of the proposed measures on the ecosystem.

# Central research question and sub-questions

## 2.1 Research question

The main research question for the project is going to be divided into two parts. For the reason that, two applications are needed in order for the answer to be found.

Main Research Question of the project:

What will happen to the populations of deer, cattle, horse and geese if releasing a number of foxes in the preserve (with the number of foxes being the free variable)?

Main Research Question for this research paper:

How do the herbivores and the geese compete for the grass in an enclosed area?

## 2.2 Research sub-questions

The research sub-questions are questions which derive from the main research question, and provide the path to the answer of the research paper.

Sub-Research Questions for this research paper:

* + 1. What is the rate of grass consumption of each animal?
    2. How do animal populations change as a result of grass availability?
    3. What are the populations of each animal?
    4. How can the start data and historical data help shape existing mathematical models to an equation which fits the problem in Oostvaardersplassen?
    5. How can the application hold all the implementations that are being asked?

# Research Methodology

The methodology explored in this project reflects the competition for food, taking place between herbivores and geese, in an enclosed ecosystem, Oostvaardersplassen. By means of collecting data and modelling equation based on the data, the research will then attempt to provide an accurate prediction based on fluctuating data. The **Data collection** is based on the information found on the Website of Oostvaardersplassen1.1 (Startpagina Staatsbosbeheer. Het zit in onze natuur. n.d.), which is related to the numbers of herbivores and geese during different seasons, the amount of grass they eat, birth rate, death rate and any other related data.

The **Equation research** is mostly focused on the equations of the grass growth. The research conducted to find equations is based on literature2.2 (Gotelli, N. J. 2008). Transforming grass amount into actual weight so a comparison can be made to the amount of food the herbivores and geese are eating.

Once the data collection process and equation research will be finalized, the creation of the application model will begin. By creating class models of UML[[1]](#footnote-1) will help to visualize how the application will look like and what it should do. As soon as, the UML model for the application is completed the focus then turns to the back-end work, implemented using Java. After having the engine and the whole data of the Oostvaardersplassen in the program, the application will then display in a GUI[[2]](#footnote-2), by JavaFX[[3]](#footnote-3).

During the project development, several limitations may occur, that could harm the result of the application. Some of those **Limitations** for this research are the time frame which project needs to be finished. The information availability constraints which might be lacking data or not accurate at all. Another challenge is the interdependence on the other group that is investigating relating variable. This research has limited scope to Oostvaardersplassen preservation.

The **first sub-question** is getting the information about the *grass consumption* of each animal. The way, in which the answer to this question will be given, is by researching about the amount of grass each of the animals in Oostvaardersplassen needs to continue living. There are a lot of resources with information in regards to the grass consumption of the herbivores. Unlike the herbivores, the geese were lacking resource information and sources. Thus, this research deals with only the most similar specie that resembles the herbivores found in Oostvaardersplassen. Then data will be taken from those species and followed with an implementation in the application.

In concordance to the website3.3 (Intake requirements n.d.), in regards to the data collection concerning with the food consumption of the *Red Deer*, it shows a distribution of a 50/50 rate of male/female dears. By means of data shown in a graph, it was deducted that the average deer weights about 110kg, and consumes about 2.5kg of Dry Matter each day.

Per the website*4.4* (Konik 2016), used to collect data about *Horse* food consumption, the average horse consumes every day around 2.5% of DM[[4]](#footnote-4); depending on the horse‘s body weight. Per the source, the horses in Oostvaardersplassen weigh between 350kg-400kg, it was decided on taking an average body weight of a horse of 375kg, which consume 9.4kg of DM each day.

From the source5.5 (Cattle 2017), used to generate information about the food consumption of a *Cow*, can be deduced that the average cow consumes 2.5% of its body weight in DM each day. The average weight of a cow in Oostvaardersplassen is 600kg, which means that each cow consumes 15kg of DM on average every day.

Due to lacking information in the data collection in regards to the food consumption of a “wild *Goose*”, a farm goose was decided to be taken as a source for indication. Per the source*6.6* *(E. Joyner, N. Jacobson, & D. ARTHUR, n.d.)*, the average goose consumes everyday around 0.15kg of DM.

To answer the **second sub-question**, research needs to be done about what is the formula that most fit the situation. To deduce how the availability of grass would affect the animal's population that are leaving in the ecological preservation.

The formula that was used in the application calculates the population growth rate of a specific species, given the specific species’ population, intrinsic rate of increase, carrying capacity, species’ competing populations, and their competition coefficients. The grass is a new variable that was introduced into the formula, to test the effect of the grass on the herbivores living there. The improved formula now takes the grass consumption of the herbivores together with the available grass in Oostvaardersplassen. To test the effect of how animal populations, change, because of grass availability, the application needs to confirm all the inputs given. Then the system will use the formula to predict each year, protracted until there is no available grass to be consumed. The application will draw a graph of the effect of the grass availability on the herbivores, showing the effect on the population over years if there is available grass to consume. Therefore, the application will not continue the prediction for the rest of the years where there is no available grass to consume by the herbivores. Which means that starvation will be reached by the animals.

To check the accuracy of the formula, the group made many tests that were successful. One of the test, that was taken, was taking the figures of 1992 of the historical data and put into the application to test the outcome prediction. The figures that were used in the test prediction were: 170 cows, 45 deer, 85 horses and the prediction was for 20 years. Just as expected, the prediction came out very like the reality of the historical data, by the fact the deer population raised enormously and the cows were reaching towards extinction. One of the only things the application itself can’t predict is the weather effects, such as cold winter/warm summer, on the herbivores. Therefore, the accuracy of this application is sufficient for this research’s purpose.

The way in which the **third sub-question** will be answered is by getting the existing numbers, of Oostvaardersplassen herbivores and geese, from the given resources, that were received, and information, that is on Oostvaardersplassen website. Afterwards, the process of implementation of those figures in the application will begin so that the outcome would be as accurate as it can be.

The population’s amounts of the herbivores were referenced per 2015. After some research with calculations and some small assumption, it is now known what the estimated herbivores numbers in accordance to 2016.

Per May 2015, there were 250 cattle, or cows, up to May 2016, 80 cows died. The assumption made is that there were 60 cattle born on average for the last few years. This means that there are an approximate 230 cows which are now living in Oostvardersplassen preservation. In accordance with May 2015, the number of Konik horses was an estimate of 1250, up until May 2016. Out of which 380 horses died, and under supposition is the number of new born which is 250, on average per last few years. Thus, resulting in a population of 1120 horses living in the conservation. Lastly, the Red deer population is counted to be 3200 up to May 2016, in accordance to May 2015. The death rate indicates that 970 deer died, during the past few years. There is an estimate of 700 dears which were born average for the last few years, which means the deer population coming to a numeral of 2930 deer.

In the **fourth sub-question**, historical data of Oostvaardersplassen needs to be accessed. As well as mathematical models, would be fitted to find an answer a part of the problem this research attempts to answer.

The equation, used in the mathematical model, is a modified version of the competitive Lotka-Volterra model2.2 (Gotelli, Nicholas J. 2008). This model calculates the population growth rate of a specific species, given the specific species’ population, intrinsic rate of increase, carrying capacity, grass availability, competing species’ population and their competition coefficients.

The modification made to this model was the introduction of an extra variable, which measures the grass availability. The current grass amount was given as a source to add into the equation. The addition of the grass into the nominator and denominator of the equation, to set the variable to 1. A detailed description along with a full list of variables and explanations can be found in the appendix.

As well an excel sheet was provided, with the population numbers and total births/deaths for each of the three-herbivore species. From there, calculations based on the individual birth/death-rate for each species were involved. Using SPSS’ [[5]](#footnote-5)Curve Fit functionality, the correlation between the population and individual birth/death-rate, gave some of the variables needed to be used in the mathematical model. A full list of these variables can be found in the appendix.

To find the last variable, the competition coefficient, the formula used a separate equation7.7 (Schoener, T. 1974). This involved researching each species’ dietary distribution and comparing them against each other. Then multiplying these numbers by the species’ relative consumption amounts, so that it would account for the differences in consumption between species as well.

*Competition coefficient numbers*

Finally, a third equation was used to calculate the total grass consumption for each species. While the model did not need this data as a variable, however, it was required to have to answer the main question of this project. The third equation that was introduced is a straight forward equation, which takes the total available amount of grass in kilograms, after converting the area of dry grass into kilograms and deducting from it the amount being eaten by all herbivores in one year in kilograms. The equation of consumption for each animal looks like this:

Deducting the total amount of grass eaten by each herbivore on an amount for each year, from the total grass available, brings the total grass left after all the years calculated.

To convert the area of DM grass in Oostvaardersplassen, it was needed to do a research of how to convert the area to weight. One of the sources (Co, n.d.) 8.8, is a company who sell grass for golf clubs, and they sell it in pallets which each pallet covers 450feet of the area (137.16m) and weigh 2250lbs (1020.583kg). A factor which needs to be taken into consideration that the grass height when being sold, to the customer, is at 0.3cm height. Considering that the area of DM grass in Oostvaardersplassen is 20,000 square meter, which means it is required to have 479 pallets of grass to cover all this area, which gives the following calculation:

The grass at Oostvaardersplassen is at around 14cm per 2015, which means the available amount of food at Oostvaardersplassen is:

Although confidence was to be found in the formulas and data as presented, there were some issues with the data collection that could not be solve. An instance is the lack of available data for certain species. As such, certain assumptions were made to account for these issues. A full list of issues and assumptions with regards to the data collection can be found in the appendix.

To implement all the information that is collected, for the **fifth sub-question** the use of both front-end development and backend development, with Java and JavaFX. With the intention of showing graphs, which outcome is based on the input that will be inputted by the user.

Since the application is built dynamically in the *front-end development*, the best choice for creating the Graphical User Interface (GUI) was by utilizing Scene Builder[[6]](#footnote-6). Scene Builder was a shaped fit, in regards to the application’s needs, not only because of the affluent maintainability but also due to its support; as well as the trivial factor of previous work experience with this tool.

The GUI was designed with ease of use in mind, to be simple yet effective. It consists of Menu Bar, Text Fields, Buttons, Radio Buttons and Graph, which visually represent the data.

Inside the *Menu Bar,* three main items can be found. A primary item is the close functionality, which allows the user to exit the application, and is found under “File -> Close”. Another item is in “About us”, which opens a window with a brief introduction about the application creators.

“Cattle”, “Red Deer”, “Horses”, “Geese” and “Years” are the *Text Fields* which prompt the user to enter Custom Data, numerical values specifically, that will be used in the Prediction model. The fields are checked by application for correct entry; if the user enters a word value instead of a numerical one, or leaves area empty – an error message will be displayed.

The predominant *buttons*, for the application, are the ones which influence the most the outcome of a prediction. “Predict” is one of the buttons, and its task to take entered data and sends it to Model to execute calculation, then display results in View. In addition to the prediction, the “Predict” Button would also print a message to the console about the grass availability at the end of the calculation. A second button is “Show Historical Data”, which draws the chart of historical data for cattle, horses and deer from 1982 to 2015. The last button resets the Text Fields and Graph view so that the user can renter data for a new prediction, entitled “Clear Data”.

The main purpose of the *Radio Buttons* is to manipulate the chart view. The user can select to display one or more preferred animal graphs or use “Totals” button to show all graphs together.

Since the application displays its results visually, by drawing charts which then will be compared and analysed by the user, the *Graph View* takes up the largest part of the application window. The chart will automatically adjust its scale to given timeframe and graphs. Each animal is assigned a unique colour for better readability.

In the *backend work*, the development of the software side, the language the code was written in is Java. By using classes and methods, which are referred to by name and invoked at any point in a program to get a functionality. Below can be found a brief description of the main methods that make the application functional, which have a more direct association /involvement towards the frontend work.

The core controller behind the *buttons* functionality found on the GUI, for this application, are the predominant methods. One of the methods is *handle Compute,* which makes the prediction by taking all the text fields as input and puts them inside the formula. By way of using a for loop to predict each year, then showing the output on the graph. *handle Compute* would also print to the console the amount of grass left each year; by taking the text fields as input to deduce the amount of available grass each year. A second significant method is *handleHistoricalData*, which shows all the historical data of the nature preserve since 1983 up to 2015. Both methods have implemented a *disabling* option, which can be pressed to compute/show historical data buttons again after the first prediction has been made. A third considerable method used to control the buttons is *methodhandleClearData*, which clears the data of the prediction or the historical data which was shown in the graph; enables the show prediction/historical data after the clear data button was pressed.

A special type of buttons used in the application are *RadioButtons*, means that only one button at a time can be selected. There four radio buttons used in the application. The first button is entitled *handleAppearanceRedDeer* and can shows and removes the line of the dears on the graph. A second button is the *handleAppearanceHorses*, coupled with the showing and removing the line of the horses from the graph. *handleAppearanceCows* is the third button, and it shows as well as removes from the graph the lines dedicated to cows. Finally, the *handleAppearanceGeese* button, which shows as well as removes from the graph the lines dedicated to geese.

Another aspect which stands out is the *TextFields* section. Which is a method that takes all the text fields as input then changing them from text field property to a string. Following with a transition from a string to a double, to push it into the formula and make the prediction. This process is true for cattle input, horses input, deer input, geese input and years input.

The menu functionality has two main methods. A first method is the *handleExit*, found under file with its main task to exit the application. The second method is *handleAbout,* and is used to show the creators names for this application in an Alert window, and is located under the About us tab.

An important method which is conspicuous is the *isInputValid*, checking if all text fields are being filled correctly with inputs when the buttons have been pushed. Otherwise a warning message with information in regards to what field needs adjustments are needed, to proceed with the prediction.

The *communication* between the two applications is done via the use of sockets, which send JavaScript Object Notation (JSON) [[7]](#footnote-7)objects containing values used in calculating a prediction. The object will be sent, the application will wait until it receives a response from the other application, then the following year’s prediction will commence. The process of sending the JSON object, waiting, calculating with the new data, sending a new JSON object again will repeat until the last year that is predicted is reached. This process will be similar for both applications.

The UML diagrams used in the report are a Class diagram and a Sequence diagram. The class diagram shows the classes used to generate the predictions. The project utilizes MVC software design pattern, as it gives a clear and expandable structure to the project.

The sequence diagram has three lifelines, UI, competition and Group 1’s system. The application has been structured so that a user can input data into the user-interface and change it to their liking. A class called competition handles the predications and the communication to the other group’s system. The competition class calculates a prediction using mathematical models, waits to retrieve information on the amount of geese and grass from Group 1’s system, calculates the new values, sends a message to Group 1’s system, then saves the data and repeats the process until it has calculated the amount of years issued by the user. The data is then sent back to the UI to be drawn in a graph for the user.

# Results

After running several tests with the formula of the competitive Lotka-Volterra model together with new introduced variable G (Grass), several results were discovered. On one hand, the result was showing that cows are reaching adjacent to extinction, after about twenty years from the prediction date. On the other hand, the deer population is reproducing at a much greater speed than any other herbivore. In the first five years, the deer reproduce slower, however, after those five years, they start to take over the area of the nature preserve. This means that after fifteen years the deer population becomes four times greater than the first five years. Unlike the two herbivores, the horses start to decline downwards after a period of thirteen years.

# Conclusion

The general conclusion that can be drawn, from this research, is that after about twenty years, from now, the cows in Oostvaardersplassen will reach extinction. Per the prediction, the cows reach their peak point after seven years, and from that point, they decline downwards towards extinction. Another conclusion is directly related to the deer’s population. The deer will keep populate if they can, and if the will not be grass an issue in this competition. In relation to the graph, the deer population can reproduce in twenty years by thirty-four times. This means that the deer can reach its peak point after twenty years. In contrast to the deer population, when it comes to the horses, the result shows that the horses are reaching their peak point after thirteen years from the prediction day. That point insinuates a slight declining in the population size each year, but extinction will not be reached.

# Recommendations

Per the conclusion and the result that was faced, several important recommendations can be made towards the client of Oostvaardersplassen. One of the most important recommendations that can be given is to expand the territory of the dry land, and potentially to dry more land to allow cows to reproduce in an open environment. Another suggestion that can be made is to bring more cows to the nature preserve, and considering to get rid of at least half of the deer population. The reason for such can explain that in nature the deer reproduce too fast, and means that they are taking away an important amount of food from the cows; due to the fact, they share the most surface for food with them cows.

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Source of grass conversion to kilograms   
[https://www.reference.com/home-garden/much-pallet-sod-weigh-390e9d062e1a93a8#](https://www.reference.com/home-garden/much-pallet-sod-weigh-390e9d062e1a93a8)

# Appendices

## 8.1 Calculations

**Calculation of the effect of competing species on the growth of species i.**

* refers to the population growth rate of species *i*.
* refers to the intrinsic rate of increase of species *i*.

The intrinsic rate of increase is a species’ growth rate without changes in birth/death rates due to population numbers.

* refers to the population of species *i*.
* refers to the total number of competing species.

Note that this does NOT mean the total population of all competing species.

* refers to the grass availability.

This variable is effectively , with the baseline being the current amount available.

* refers to the carrying capacity of species *i*.

The carrying capacity is the maximum amount of a specific species that its’ environment can support.

* refers to the competition coefficient of species *j* upon *i*.

This refers to the extent that each individual of species *j* affects species *i*’s growth rate.

Note that is equal to 1.

**Calculation of the competition of species *j* on species *i*.**

* is the competition coefficient
* refers to the relative utilization of resource *h* by species *i*, computed as a fraction of the total utilization of all resources for species *i*.

## 8.2 Dietary distribution in percentages.

**Cattle diet1:**

Graminoids 88%

Forbs (Herbaceous Plants) 3%

Shrubs (Woody plants) 8%

**Red Deer diet2:**

Graminoids 20%

Forbs (Herbaceous Plants) 24%

Ferns (Herbaceous Plants) 10%

Browses (Woody plants) 44%

**Konik Horse diet3:**

Graminoids 86%

Herbaceous Plants 12%

Woody plants 2%

**Geese diet4:**

Graminoids 83%

Herbaceous Plants 15%

Insects/Snails 2%

1. Mean percent composition of important forages in diets of cattle in South-eastern Oregon during summer-winter 1980-1981 <http://oregonstate.edu/dept/eoarc/sites/default/files/publication/309.pdf>

2. The composition of red deer diets in the Less Xingan Mountains, northeastern China during summer-winter 1991-1992. <http://rcin.org.pl/Content/12794/BI002_2613_Cz-40-2_Acta-T43-nr6-77-94_o.pdf>

3. General diet composition (% of total number of bites) of konik and donkeys in two Belgian coastal dune nature reserves during summer-winter 1999-2000 <https://www.researchgate.net/publication/242600674_Feeding_ecology_of_Konik_horses_and_donkeys_in_Belgian_coastal_dunes_and_its_implication_for_nature_management>

4. The food habits of Greylag and Barheaded Geese in the Keoladeo National Park, India during winter 1985-1986. <http://wildfowl.wwt.org.uk/index.php/wildfowl/article/view/774>

## 8.3 Competition Coefficient Calculations

Competition coefficient calculations, **BEFORE** calculating the difference in total consumption.

CATTLE = 1 DEER = 2 HORSES = 3 GEESE = 4

A\_11 = 1

A\_12 = = = = 0.2832

A\_13 = = = = 0.9748

A\_14 = = = = 0.9401

A\_21 = = = = 0.6340

A\_22 = 1

A\_23 = = = = 0.6346

A\_24 = = = = 0.6214

A\_31 = = = = 1.010

A\_32 = = = = 0.2937

A\_33 = 1

A\_34 = = = = 0.97

Competition coefficient calculations, **AFTER** calculating the difference in total consumption.

CATTLE = 1 DEER = 2 HORSES = 3 GEESE = 4

A\_11 = 1

A\_12 = 0.2832 \* = 0.0472

A\_13 = 0.9748 \* = 0.6109

A\_14 = 0.9401 \* = 0.009401

A\_21 = 0.6340 \* = 3.804

A\_22 = 1

A\_23 = 0.6346 \* = 2.386

A\_24 = 0.6214 \* = 0.03728

A\_31 = 1.010 \* = 1.612

A\_32 = 0.2937 \* = 0.07811

A\_33 = 1

A\_34 = 0.97 \* = 0.01548

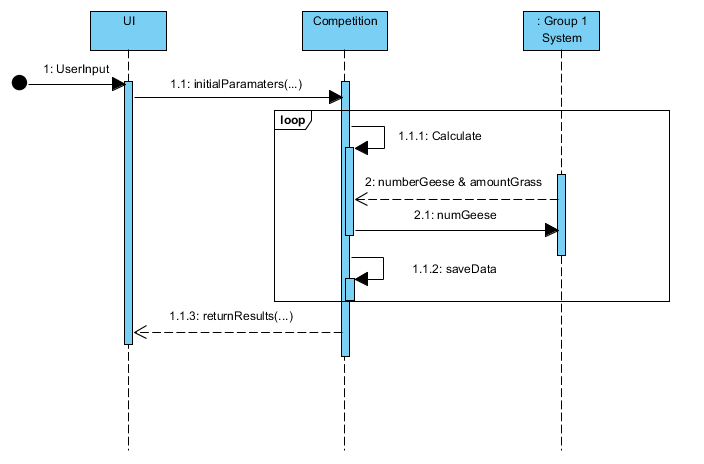
## 8.4 Assumptions

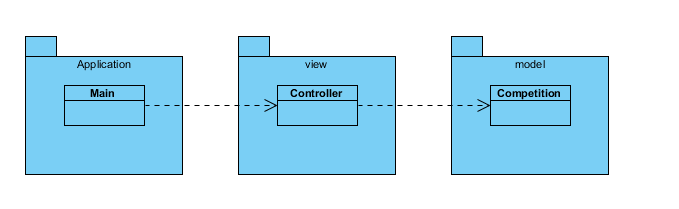
Below is a list of issues with the data collection, followed by the assumptions made for them where needed.

* One of the assumptions was a linear correlation between grass availability and carrying capacity, which may not hold in real-life scenarios.
* The formula for competition coefficients uses percentages of dietary overlap but does not consider differences in the amount of consumption.
  + Multiplying the coefficients by the relative consumption amounts to find a more accurate number.
    - Using daily Dry Matter intake for relative consumption amounts, so this calculation does not account for the difference in digestive efficiency.
* The model does not account for the separate types of geese.
  + By using the three species of geese present and averaged them as one species.
* For all species, the dietary information was not available for the specific region modelled.
  + By using the dietary information from other locations.
* Spring data was unavailable for Konik horses,
  + - Averaging the summer-winter combined since the research displayed seasonal percentages.
* Terminology was not completely consistent
  + Categorized was done by using the Konik Horse’s data from descriptions.
    - Not being experts in biology errors cannot rule out in dietary descriptions completely.
* The numbers used to calculate the competition coefficient don’t add up to 100% due to rounding.
* The dietary information for the specific types of geese was too difficult to find.
  + Thus, the research used dietary information for Greylag and Barheaded geese combined.
* The only available dietary information for geese was limited to the months of November-April
  + Finding dietary information for other seasonal periods proved impossible, however, the research uses it anyway.
* The dietary information for Heck Cattle was problematic to find.
  + Thus, dietary information for Wild Cattle is used instead.

## 8.5 UML Diagrams

**Sequence Diagram**



**Class Diagram**

1. UML – Unified Modeling Language is a general-purpose, developmental, modeling language in the field of software engineering, which intends to provide a standard way to visualize the design of a system. [↑](#footnote-ref-1)
2. GUI – Graphical User Interface is a type of user interface that allows users to interact with electronic devices through graphical icons and visual indicators such as secondary notation, instead of text-based user interfaces, typed command labels or text navigation. [↑](#footnote-ref-2)
3. JavaFX - software platform for creating and delivering desktop applications, intended as the standard use of GUI library for Java. [↑](#footnote-ref-3)
4. DM – abbreviation for dry matter; [↑](#footnote-ref-4)
5. SPSS – Statistics is a software package used for logical batched and non-batched statistical analysis. [↑](#footnote-ref-5)
6. Scene Builder – is a visual layout tool for JavaFX applications. The JavaFXScene lets a user rapidly project a JavaFX application user interfaces, without coding. [↑](#footnote-ref-6)
7. JavaScript Object Notation (JSON) – is a lightweight data-interchange format. [↑](#footnote-ref-7)